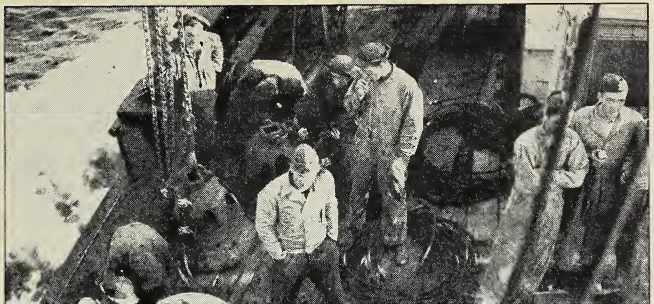

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Living Chemistry

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PREFACE

Living Chemistry makes the study of chemistry a living experience. It was vitten because the authors felt that there was an urgnt need for such a book. Some twelve years ago th authors became aware that chemistry, as it was beg taught, was attracting only a small percentage o high-school pupils and that many of those who we taking chemistry were doing so to satisfy colleg entrance requirements rather than to satisfy a geine interest. With unwavering faith in the imptance of chemistry in daily living, the authors t out to discover the problems related to chemistr in which young people are interested and to reorgaze the course in chemistry so that it would exert real influence in their daily living. These problem were discovered and the reorganization accomphed in a twelve-year period, during which the autrs worked intimately with their pupils. The matal presented in *Living Chemistry* has grown out of ts experimentation.

The units in this book hav been selected because they are the ones most consisntly suggested by the many groups of pupils who ve worked with the authors. The problems are re problems which have been proposed, year after ye by pupils. The information presented for the sction of each problem is based on the researches of hese same groups of pupils. Actually, then, these periences in chemistry were organized through -operative planning and are based on the problems d interests of pupils.

The experimentation has rlted in many interesting and valuable findings. st, pupils learn just as many facts and concepts of mistry through the solution of meaningful problem elated to chemistry as they do through the study the usual systematized organization of chemistry econd, the authors have evidence to show that ough the problem approach more of these facts d concepts are retained and applied to every living. Third, pupils who have taken this cou in chemistry have fared as well in college chemist as those who have taken the traditionally organi course in chemistry. Fourth, the authors h discovered that growth in such objectives as ability to think scientifically and the formation of desirable attitudes, habits, appreciations, and ideals is more certain to result from the solution of meaningful problems than from the study of organized facts and concepts.

The unique procedure followed in planning this course in chemistry has resulted in an organization of materials quite different from that of most chemistry books. Part I, "Fundamentals of Chemistry," includes the minimum material which is necessary to give pupils enough background to make possible a direct attack upon the meaningful problems which are related to chemistry. Part II, "Chemistry of the Individual," deals with problems of a personal nature. Part III, "Chemistry of the Home," contains a discussion of problems related to the home. Part IV, "Chemistry of the Community," gives consideration to problems of the immediate and the world-wide community. Though Part I contains the needed basic facts and concepts of chemistry, it should be understood that in Parts II, III, and IV many additional facts and concepts are presented as they are needed for the solution of practical problems.

The reader will find many unusual features in this book. This high-school chemistry has given direct consideration to vocations and hobbies related to chemistry. Throughout the book social implications are stressed, with special emphasis upon consumer implications. There are exercises at the end of each problem and objective tests at the end of each unit. In "Problems for Further Study" provision is made for pupils whose interests are varied and for those who care to solve additional problems. Years of searching on the part of the authors and their students have made possible an excellent bibliography for each unit. The references listed in each bibliography have been carefully selected. The purposes listed near the beginning of each unit are a composite of those which have been set up by pupils.

The material has been organized and written so that it can be read and understood by senior-high-school pupils. Indiscriminate use of words

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which are not familiar to pupils has been avoided; and when an unfamiliar word is used, it is defined, or its meaning is otherwise made clear, at the place where it is first used.

The authors have intentionally included more problems than can be given full consideration in one school year. This provides an opportunity for teacher and pupils to make choices based upon the needs and interests of the group.

The authors feel that the material presented will contribute to better living. An inspection of the table of contents shows the many aspects of everyday living that are covered by the book.

The authors are greatly indebted to the hundreds of pupils who have generously and enthusiastically participated in the formulation of the material in this book. They also wish to acknowledge indebtedness to their wives, Jewell Easley, Ethel Bush, and Virginia Ahrens, for reading and criticizing the manuscript. The authors are grateful to Dr. Robert J. Havighurst, Professor of Education, University of Chicago, Dr. V. T. Thayer, Educational Director, Fieldston School, Fieldston, New York, A. N. Zechiel, Curriculum Assistant in the Eight Year Study, Progressive Education Association, and Gilbert S. Willey, Director of Instruction, Denver Public Schools, for their advice and encouragement; to Peter C. Holm, Sam R. Hill, John J. Cory, and Roscoe Hill, principals of Denver high schools, who graciously and willingly gave them encouragement and freedom for experimentation; to Dr. E. C. Harrah, Professor of Zoology, Colorado State College of Education, who contributed many helpful suggestions; to J. Howard Williamson, teacher in the Manual Training High School, Denver, Colorado, who read and criticized portions of the manuscript and provided many helpful materials; and to Leon K. Whitney, teacher in the South High School, Denver, Colorado, who also read and criticized a portion of the manuscript. The authors are also indebted to many commercial firms and government agencies for permission to reproduce many photographs and illustrations.

THE AUTHORS

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LIVING CHEMISTRY

PART I

FUNDAMENTALS OF CHEMISTRY

The study of *Living Chemistry* will help you to understand and appreciate the wonders of chemistry

UNIT 1

Chemistry Improves Man's Living

Chemistry is life. Are you aware of the fact that every living thing is dependent upon chemistry for life? This fact will be more clearly understood when you become aware that all the materials of plant and animal life and all the changes that occur in plants and animals are chemical in nature. In fact, chemistry is the science which deals with the composition of all materials and the changes which those materials undergo.

The human body is a chemical manufacturing plant. The food that is so essential to supplying energy and to building tissue in our bodies would be useless except for this fact. Food must be made soluble through the chemical processes of digestion. The food made soluble by digestion can supply energy and build tissue only through chemical processes which are carried on within the body cells. The glands of your body manufacture substances which are distributed to all parts of the body. These substances may determine such important characteristics as whether you are a giant or a dwarf, whether you are normal or subnormal in intelligence, and whether you are fat or thin. Moreover, your nervous system, which makes it possible for you to distinguish between hot and cold, provides you with a sense of smell, and makes it possible for you to see, feel, and think, is dependent upon chemical reactions.

The close relationship between chemistry and plant life may easily be shown. Plants could not exist unless certain chemical changes occurred. From the time the seed is placed in the soil, chemical changes are continually taking place which make possible the development and life of a plant. Chemical changes within the plant make possible the absorption of carbon dioxide from the air and the use of it in the manufacture of food and of other plant cells. As this process is being carried on, oxygen, which is essential to all animal life, is released to the air. Through these chemical changes man and all animal life are assured food, shelter, and oxygen. Thus, plants make life possible.

All common products used every day for the preservation and protection of life are chemical products. The drugs which doctors prescribe for curing diseases, the antiseptics you use to prevent or hinder infection, the tooth paste you use to keep your teeth clean, the soap which assures body cleanliness, are the products of chemical laboratories.

Industries, through the knowledge and use of chemistry, have provided many products which make life more pleasant and livable. For example, cosmetics have greatly improved the appearance of both men and women; colorfast dyes have made clothing and materials more colorful and pleasing to the eye; and rubber is indispensable in the manufacture of the modern high-speed automobile, which has so greatly added to the enjoyment of living. Other chemical products which are serving to enrich living are rayon, "Nylon," "Cellophane," metallic alloys, and plastics.

No truer statement could be made than "Chemistry is life." It will be one of the purposes of this book to unfold for you the story of living chemistry. To help in the achievement of this purpose let us look into the many phases of modern life to see the changes which science, especially chemistry, has brought about and the ways in which man's living has been improved.

The study of chemistry has helped man to understand disease. A child born at the time that Columbus discovered America could expect to live only about fifteen years. Children born today can expect to live to be sixty years of age. Seventy-five years ago the center of health and medical activities of the world was Paris; yet, even in this relatively enlightened place, the death rate from surgery in the hospitals was startling. It has been said that, at that time, of every three persons operated on one died from the knife, one died from the anesthetic, and one lived to be thankful. How different it is today when very few people die from the effect of the knife or the anesthetic! Chemistry has contributed greatly to this increase in life expectancy and to the remarkable decrease in deaths from surgery.

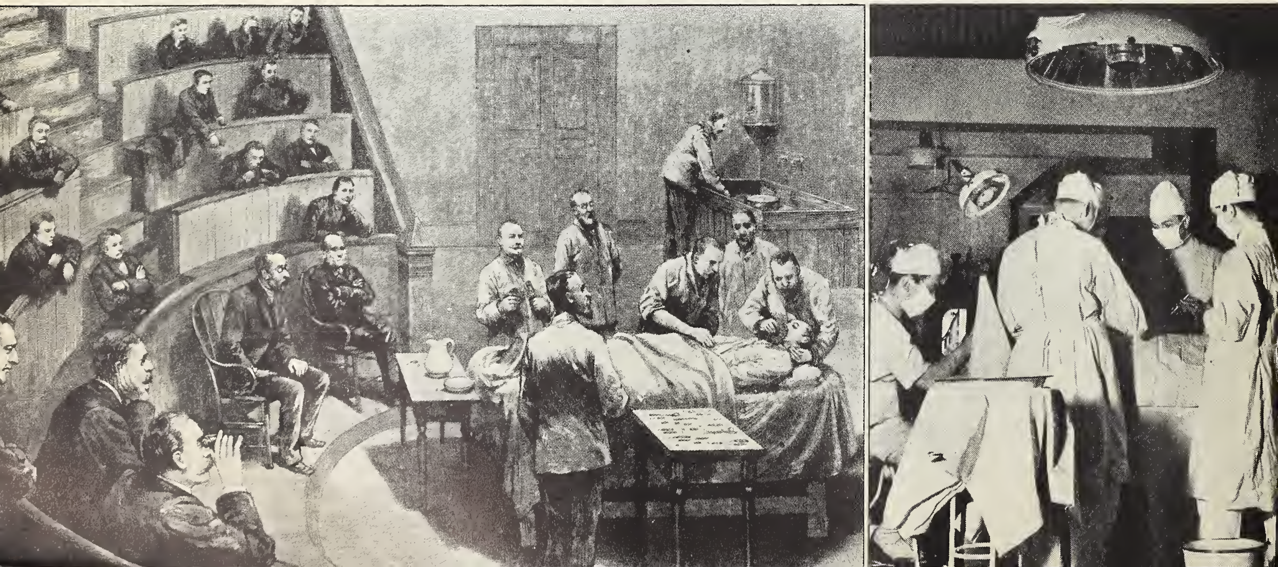
Pasteur (1822–1895), a truly great French chemist, and Lister (1827–1912), an English physician and chemist, did more to increase the average age to which man might live than any other two men. They showed the use of such chemical substances as antiseptics, serums, and vaccines. Pasteur proved beyond doubt (although he had great difficulty in doing so) the relationship between certain kinds of microorganisms (bacteria and protozoa) and specific diseases. The germ theory of disease, which we all accept now and talk about glibly, was given to the world by Pasteur. Lister revolutionized surgery by demonstrating the efficiency of antiseptics in the treatment of wounds.

Many explanations of diseases had been prevalent before Pasteur. During earliest times, people thought that illness was caused by demons inhabiting the body. The art of healing was dominated by superstition, witchcraft, and misinformation. Even learned men thought that infection and disease were due to such things as committing sinful acts or the wrath of gods or enemies. Surgery was practiced by barbers, with no chemical agents to lessen pain or prevent infection. Then later it was held that a sick person was filled with so-called bad humors and for a cure should be bled. Still later it was believed that disease generated spontaneously within a person.

It remained for Pasteur to prove that disease is not generated spontaneously, but that it is caused by the growth and accumulation of harmful microorganisms within the body. His experimental work with microorganisms led him to discover some of the fundamental laws of health which we accept today as commonplace. Such health rules as isolation of the sick and vaccination and inoculation for the prevention of certain diseases probably resulted from the work of Pasteur. Today, owing to the pioneering work of Pasteur and others, most of the diseases caused by microorganisms have been conquered. In this modern day, if you become ill, you have at your disposal a competent physician and adequate hospital facilities. It is customary to use them, but it is important to remember that we have not always enjoyed these benefits. We must thank hundreds of physicians, chemists, and research workers for these services and benefits.

Chemical substances that are benefactors of mankind: antiseptics and anesthetics. Through a process of continual experimentation many new chemical substances with antiseptic properties have been discovered. As recently as one hundred years ago, many people died of infection that developed from slight injuries. Now, owing to the work of the chemist, it is not usually necessary to suffer pain and death from infection, because "chemicals" commonly known as antiseptics and disinfectants may be used to destroy the disease-producing microorganisms.

These pictures show some of the differences between the surgical methods of 1888 and those of the present. Chemistry has contributed much to bring about this improvement



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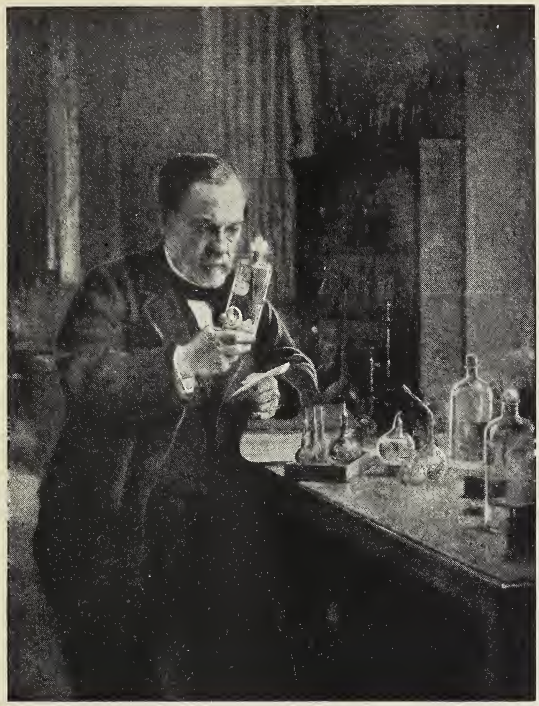
Ewing Galloway



Louis Pasteur, the famous French scientist, propounder of the germ theory of disease and a pioneer in the use of vaccines to control disease

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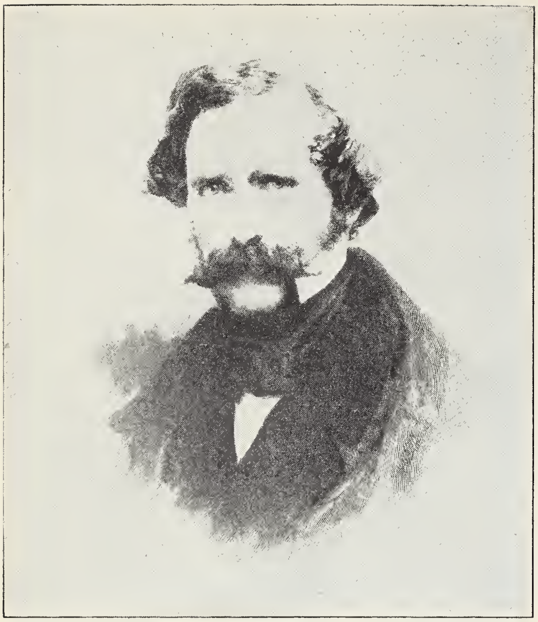
Treatment of an abscess of the arm by a Dutch surgeon. Copper engraving, 1695. Contrast this scene with that of the operating room of a modern hospital

Ether, a substance which may be used to banish pain, was given, as an anesthetic, to a human being for the first time in 1842 during an operation by Dr. Long of Georgia. Dr. Long was criticized so severely for the use of ether that he was forced to abandon the practice of using it. It remained for Dr. Morton of Boston to establish its use on an accepted basis in 1846.

Before that time, operations were performed, after the patient had been strapped securely to a table, without the use of desensitizers. Earlier, in Egypt, doctors induced anesthesia by striking the patient over the head. Sometimes hypnotism was attempted. All methods were highly unsuccessful until ether was discovered. Contrast such procedures with that followed at the present time in a modern hospital, where many good anesthetics are available for use. In addition to general anesthetics, we have local anesthetics, which are now widely used by doctors and dentists to desensitize a particular area. A good example is the drug "Novocain." It was the contribution of a chemist who experimented with cocaine.

Chemistry contributes to better foods. In what ways have foodstuffs changed? At the present time we eat a varied diet of fats, carbohydrates, proteins, vitamins, and minerals throughout the year. We know, or can be told by competent physicians, what amounts and proportions of food we need and must consume for healthful living. In experimentation with foods the chemist has served humanity in many ways. He has analyzed foods to determine their content; he has enabled dietitians to make scientifically correct recipes and diets; and he has provided the knowledge of processes and materials that has made refrigeration and preservation possible, enabling us to store foods properly and to eliminate untold waste of foods.

Chemistry has made it possible for the agriculturist to grow more and better foodstuffs. Much of



William Morton of Boston, who, in 1846, established the use of ether as an anesthetic

this improvement has been due to the use of scientifically compounded fertilizers and man-made growth-producing substances such as vitamin B. Through chemistry it is now possible for the farmer to utilize waste materials and make from them desirable products. For example, cotton farmers used to throw away the seeds of cotton; now the oil from these seeds is made into edible solid fats, such as "Crisco" and "Snowdrift."

Chemistry transforms industry. Many changes have been made in the industrial world by the work of chemists. Hundreds of new vocations have arisen because new industries have been created. Entire countries have been reduced to near-bankruptcy by chemical discoveries which have resulted in the making of synthetic materials[1] to take the place of materials produced in nature.

Let us consider some industries — dye-manufacturing, the making of fertilizers, etc. — which have been greatly affected by modern chemistry.

Artificial dyes. Until 1850 all the coloring materials were made from materials found in nature. Dyers had to choose between such dyeing agents as colored vegetable compounds, minerals, and minute animal life, such as cochineal bugs. You may have heard your grandmother tell how homespun cloth was dyed with the bark from black walnuts. In those days most people lived in a world of black and white, with only a few colors to enliven their environment. Very wealthy people might have had clothing dyed with expensive natural coloring material, which was obtainable in minute amounts from the tropics, but most people had to be content with fabrics of little color. Man has always been a worshiper of the beautiful colors of nature, but, until the research chemist came along, he was never able to duplicate the variety of colors in the rainbow. Now he has gone beyond the rainbow and is able to produce delicate shades of many colors that are not to be found in nature. Observe your clothing, the furnishings of your home, your automobile, the enamel decorations in your kitchen, or such things as pens and pencils; notice how they are now being made in colors very pleasing to the eye. You must thank the chemists of the dye industry for the wonders of color.

At the present time, foods, clothing, cosmetics, and enamels are practically all colored by dyes made from a foul-smelling substance called coal tar. The chemist has been able to make synthetically so many dyestuffs from this material that it is sometimes termed "liquid sunshine." At one time, coal tar was considered a bothersome waste product in the manufacture of coke and coal gas from coal. Research with coal tar was begun in 1856 by William Perkin, a young laboratory assistant who was working for the English chemist Hoffman. He was trying to produce quinine from coal tar. Accidentally he poured the contents of two beakers together, and the result was a beautiful mauve color. Thus was born a great industry which has taken its place with the electric light and the radio in making this world a more pleasant place in which to live. The modern achievements in making dyes rang the death knell of the prosperous indigo-growing industry of India. It would be difficult to do without synthetic dyestuffs, for they make possible materials which are beautiful and which do not fade. Thousands of these dyes

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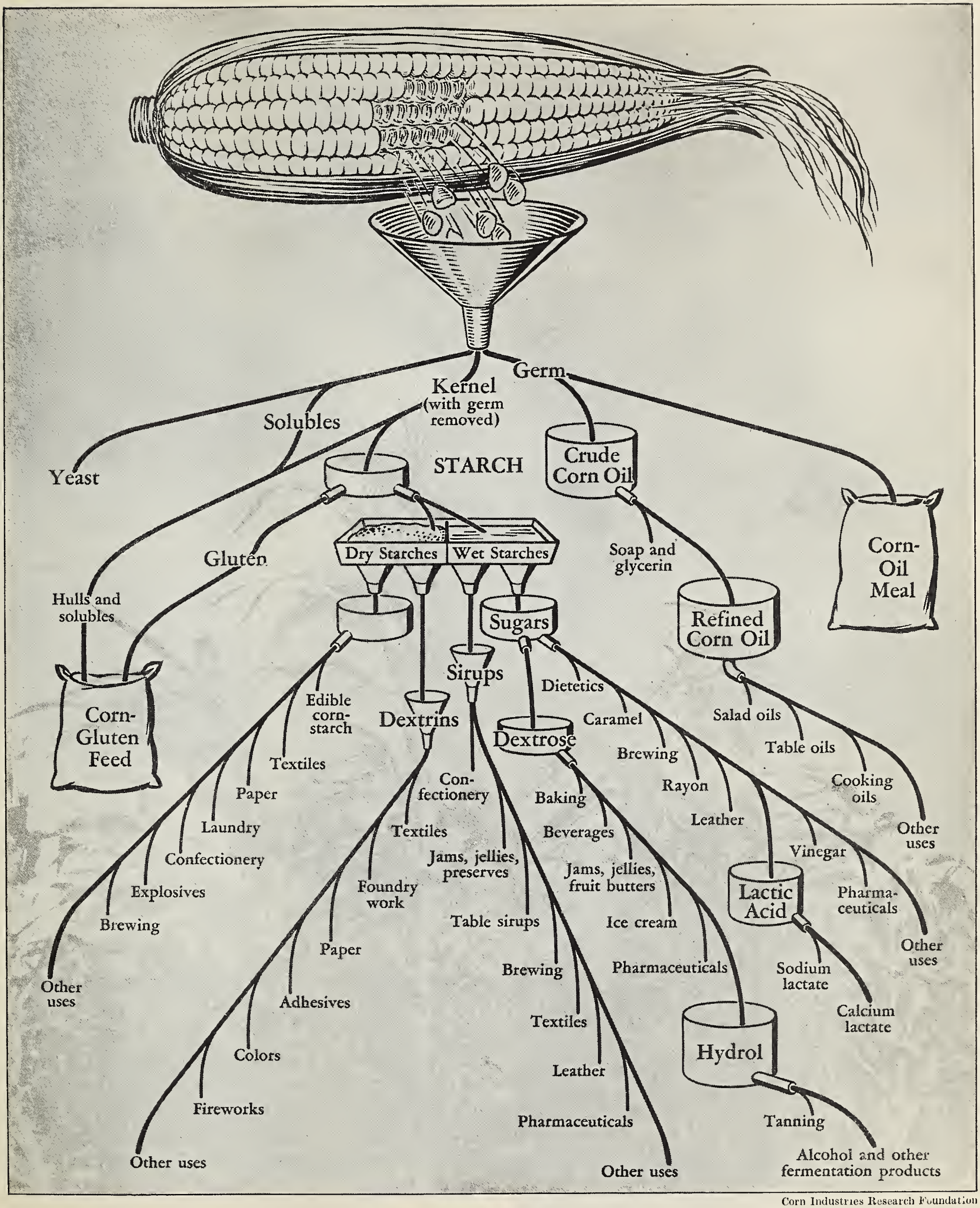
[1] Synthetic materials are those produced by man from simpler materials to take the place of similar substances produced in nature.



Corn Industries Research Foundation

Products made from corn

are now made. They are intimately connected with our modern high standard of living.

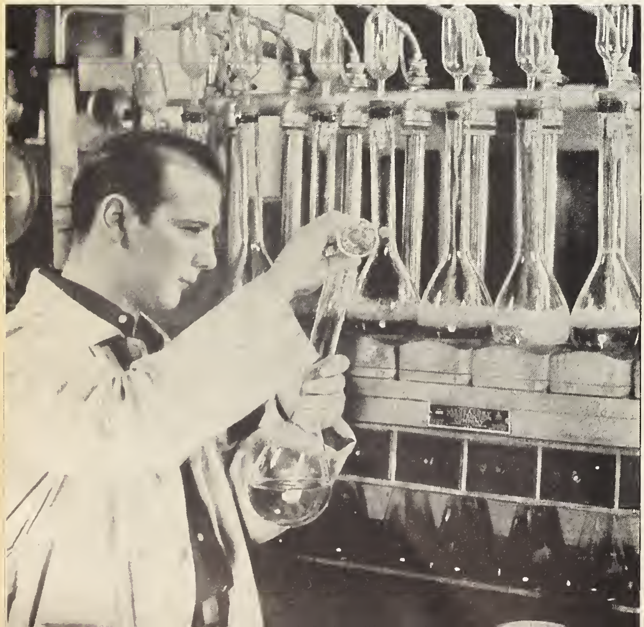
Fertilizers from air. A similar story can be told of the making of synthetic nitrate compounds by the chemists of Germany. As early as 1840 Wöhler had shown the world the nature of fertilizers and how soil can be enriched by "nitrate chemicals." But it remained for two great German chemists by the names of Haber and Ostwald to show in 1916 that nitrogen from air can be made into nitrates by synthetic means.

This knowledge is now applied in the making of fertilizers and explosives in all the civilized countries of the world. Formerly all the nitrates were obtained from the natural deposits of Chile. Now thousands of tons of fertilizers are made by the synthetic method from air. This knowledge of the making of fertilizers and their use in replenishing worn-out soils with nutrients has made it possible for man to grow better and more foodstuffs.

Chemistry clothes people. Almost every person in America today wears some clothing made of rayon or mixtures of rayon with other materials. The knowledge of how to make rayon from raw cellulose, which can be obtained from wood or cotton, was discovered by a French chemist in 1885. Today rayon, the world's most common man-made yarn, makes available to millions luxurious fabrics of a quality that only a few could previously afford. This shows in a very striking way one effect of scientific advancement upon our lives.

The food chemist analyzes foods to see what nutrients are present. He often develops new foods. He protects our health by detecting the presence of adulterants and harmful preservatives. This chemist is determining the protein content of a food

Corn Industries Research Foundation



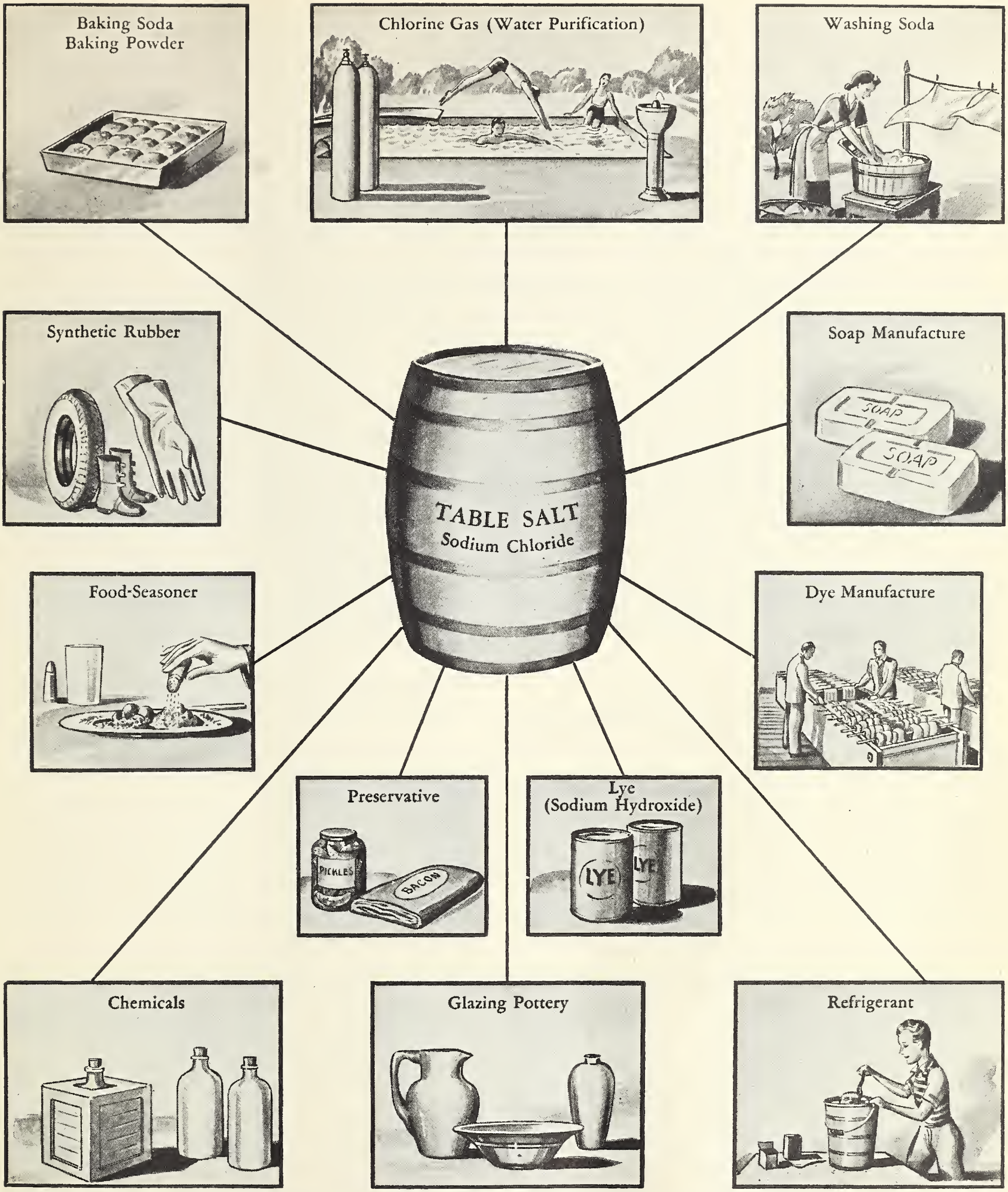
Notre Dame University

The Reverend Julius Nieuwland, who discovered the process of making synthetic rubber. Of what importance is this product today?

Man-made rubber. Another example of the achievement of chemistry in recent years is man-made rubber. Father Nieuwland of Notre Dame University, after years of research, developed a man-made rubber, using such common things as salt, limestone, water, and coal. It is now sold under the name of "Duprene" and other trade names.

In some ways, this new man-made rubber is better than that made by nature in that it is more resistant to heat, oils, and certain chemicals. While most rubber products are still made from natural rubber, they could be made from synthetic rubber.

New things from salt. Through his knowledge of chemistry, man is now able to make many useful and complicated substances out of simple ones. For example, take the common material table salt (sodium chloride); in addition to its use to make foods more tasty, chemists use it in making things as far apart as toilet soap and chemicals for controlling



Uses of sodium chloride (NaCl) in agriculture, industry, and the home rodents. The manufacture of bleaching powder, disinfectants, refrigeration materials, synthetic rubber, and many other things requires this valuable raw material. The gas chlorine, which has many important industrial uses, is also made from salt.

We can truly say that a knowledge of chemistry and an application of this knowledge to the workaday world have produced a revolution in our mode of living. This chemical revolution is probably in its infancy. Greater changes are yet to come.

What are your reasons for studying chemistry? In addition to learning more about the scientific world in which you live, there are many other reasons why you are beginning the fascinating study of chemistry. For example, some of you might say that you are studying it to prepare for college or that you are just curious about things. These are good reasons, but there should be other reasons—more specific, more individualized, and more personal—for your anticipated year's work. To help you to think through the possible purposes which you might have in studying this science, those which follow are suggested. You may want to adopt some of them for your own, or you may want to make an entirely new list.

Purpose 1. *To form the habit of thinking scientifically in all life experiences.* Scientific thinking is logical or reflective thinking.

In the past, there has been a general feeling that scientific thinking could be used only in solving the problems of science. In recent years we have come to realize that scientific thinking can be used in the solution of any of the problems of living. Therefore it is believed that the definite process of thinking revealed by your study of chemistry will aid you in solving not only the problems of chemistry, but also those that arise from life situations in general.

Purpose 2. *To gain additional knowledge of health and assist you in forming proper habits of health.* One of the shortcomings of man is that he fails to realize the value of good health until ill health overtakes him. Such a poor attitude toward health may be due partly to a lack of knowledge of the proper habits of health. One must have the conviction that the practice of the proper habits of health will ensure continued health of body and mind.

You should be aware of the part that chemistry has played and is playing in the development of healthy bodies and minds. If you could know of the physical suffering and disease caused by a lack of knowledge of foods and their improper use, you would probably realize the seriousness of the problem. Chemistry tells you of what foods are composed, how food is digested and used in the body, and many other facts that will cause you to realize the value of proper eating. Chemistry will help to protect you from dangers involved in the use of drugs, cosmetics, laxatives, antiseptics, and other commonly used preparations.

Purpose 3. *To understand, at least partially, the significant changes that have been brought about by science in the life of each individual and in society as a whole.* A child born in the seventeenth century had a right to expect to live to be only eighteen years of age. This same child born in 1941 can expect to live to be about sixty years of age. What part has chemistry played in this tremendous change?

Expectation of Life at Birth among Total Persons (White and Colored) and among White Persons by Sex, United States, from 1901 to 1937[1]

Year	Expectation of Life at Birth, Years		
	Total Persons	*White Males*	*White Females*
1937[1]	61.48	60.75	65.08
1936[1]	60.81	60.18	64.36
1935[1]	61.37	60.72	64.72
1934[1]	60.79	60.24	64.18
1933[1]	61.26	60.86	64.40
1932[2]	61.07	60.69	64.38
1931[2]	60.26	59.88	63.56
1929–1931[3]	59.50	59.31	62.83
1919–1920[4]	—	55.33	57.52
1910[5]	51.49	50.23	53.62
1901[5]	49.24	48.23	51.08

[1] Total United States. [2] United States, excluding Texas.
[3] United States, excluding Texas and South Dakota.
[4] Aggregate of 27 states; not computed for total persons.
[5] Original Death Registration States.

Scientific changes which have been brought about by the application of chemistry have resulted in many social changes. For example, men at gainful labor have been displaced by machines and by the use of new scientific processes. The application of

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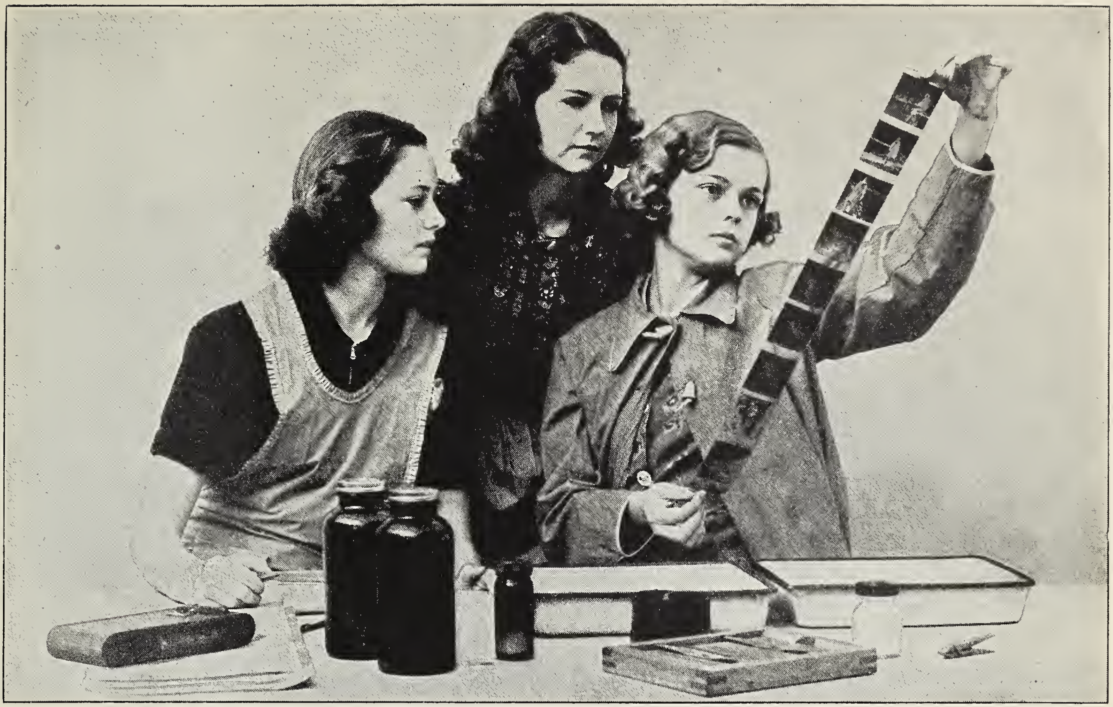
[1] Courtesy of the Metropolitan Life Insurance Company.



H. Armstrong Roberts

There are many young people who find that photography affords a fascinating and interesting hobby

chemistry to industry has, however, made possible shorter working hours, more time for leisure, and new kinds of employment.

Purpose 4. *To discover and develop new wholesome leisure-time activities.* Economists and sociologists are predicting that in the future we shall be able to have more hours for leisure. We shall work less and play more. The fact that some persons do not know how to play has brought about, at least partially, many of the modern problems involved in crime. Psychologists tell us that potential criminals usually direct their leisure time to unwholesome rather than wholesome activities.

Chemistry has some very definite contributions to make to the development of leisure-time activities, especially in the field of hobbies. This does not mean that these hobbies are to be forced upon you in this study. It does mean that you will become acquainted with various chemical hobbies. Whether or not you choose to follow one of these hobbies will depend upon your interest.

Have you ever experienced the magic of the appearance of figures on photographic printing paper during the process of developing? Photography is one of the many hobbies made possible through chemistry. Many young people, as well as adults, have become vitally interested in such chemical hobbies as chemical microscopy, the collection of minerals, crime detection, home laboratories, and home manufacturing.

Purpose 5. *To provide basic understandings which will make it possible for you to select and use goods and services wisely.* Everyone is faced with the problem of buying. If an article is to be purchased, you are face to face with the problem of selecting one of many brands. Such a situation involves choosing the best quality for the most reasonable price. Your ability to think through the maze of advertising will determine the intelligence with which you buy. Information about many of the products and services which you are now using can be obtained through a study of chemistry. This information will help you in a more intelligent selection.

Chemistry can help you to solve such problems as these: Is one gasoline better than another? Shall I use aspirin or some other remedy for a headache? How can I select a good dentifrice? What is a good laxative to buy? For a good complexion, is it necessary to buy and use many of the different kinds of face creams and lotions? What endorsements and stamps of approval can be relied upon? How can I select a good dentist?

In this day and age there is great need for you to seek intelligent answers to these and many other questions. Such questions can be answered upon the basis of biased opinions, or they can be answered by a process involving scientific thinking. Chemistry will help you to use the latter method.

Purpose 6. *To develop the ability to study and investigate intelligently a particular problem which may be of interest to you.* Problems that you meet in everyday life are generally problems that you yourself must solve. No one else can solve them for you. The success that you experience in solving these problems will depend upon your ability to carry on an intelligent investigation. The ability to investigate a problem intelligently will be made possible through practice in the use of the scientific method. The ability to gather, analyze, and classify data and draw conclusions will be of great value to you.

Many problems will be presented and others will occur to you in the various units to be considered in this course. You are certain to find some of great interest to you. During this study you should complete several major investigations and experience the great satisfaction which results from the solution of problems.

Purpose 7. *To develop an understanding of the relationship of industry to society.* Should you be willing to go back to live in the society of two hundred years ago, when each family was a unit which produced everything that was needed? Should you be willing to forego all the modern comforts of living which have been provided by industry? Are you aware of the contributions that industry has made to the production of a happier, more healthful life?

Science and industry have walked hand in hand to bring about many changes in society. In turn, society has produced changes in industry. This course will point out many of the advances in in-

You should learn to buy wisely. To do this you need to know how to interpret labels and to understand the nature of substances which you purchase. Chemistry will help you to learn these things

Ewing Galloway

Ewing Galloway

Science has brought about great changes in man's mode of transportation in the past fifty years

dustry and society, which will help you to understand many of the changes which have taken place in the development of our present social living.

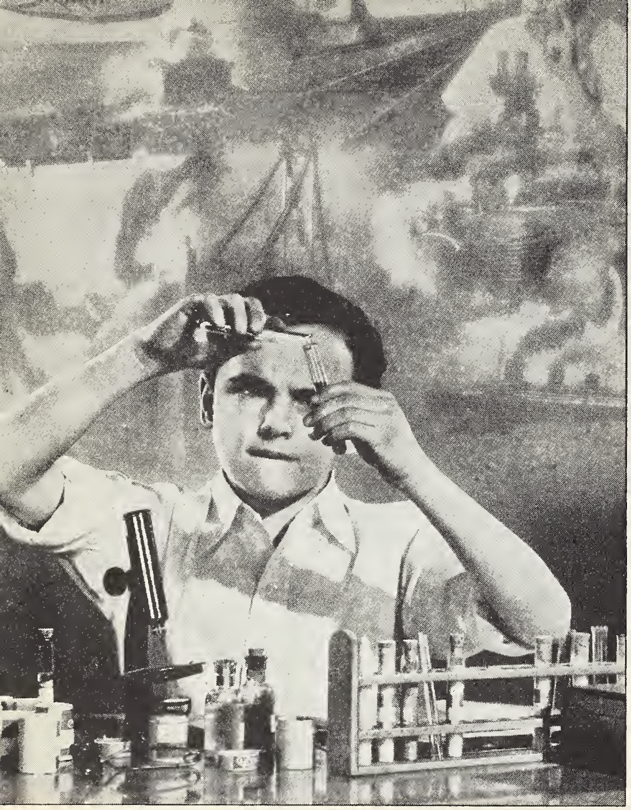
Purpose 8. *To provide an opportunity to explore vocations closely related to chemistry so that you may plan for the future more intelligently.* It is not assumed that all of you will follow a vocation closely related to chemistry. It is assumed that to be able to choose a vocation intelligently you must explore and know about many different ones. This course will provide you with that opportunity. You will learn that there are many vocations in which chemistry plays an important part. You will learn about the preparation for these vocations, the possibilities of securing employment, and many other important facts relating to the choice of a vocation.

The plan of this book. There are many different ways which might be followed in your study of chemistry to achieve these eight purposes and any other purposes that you may have. However, the plan of study followed by this book is one which other students of chemistry have liked and found to be beneficial.

You will first need to know some of the fundamental facts about matter, or the material world. Some of these facts will be found in Unit 2, "The Material World: Matter." In units following Unit 2 will be found basic information on the forces of nature, the structure of matter, chemical formulas, oxygen, hydrogen, solutions, chemical equations, acids, bases, salts, and oxides.

After you have built a thorough foundation of some of the Fundamentals of Chemistry (Part I), you will then be ready to delve more deeply into the more important applications of these fundamentals to your daily living. Therefore the units referred to above will be followed by units dealing with the Chemistry of the Individual (Part II), the Chemistry of the Home (Part III), and the Chemistry of the Community (Part IV).

At the beginning of each of the following units in this book, you will find a list of purposes for that unit and some problems to solve. Keep these in mind as you study. At the close of each unit you will find a series of questions with which you should check your understanding of the general purposes of the unit.



E. I. Du Pont de Nemours & Co.

A home chemical laboratory provides a desirable setting for many hobbies related to chemistry. The dreams of youth become the realities of the future

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PROBLEMS FOR FURTHER STUDY

1. Prepare an outline which will show the progress of science from the time of early man to the present, on the basis of the following historical periods: (*a*) from earliest man to first recorded history (approximately to 5000 B.C.); (*b*) from 5000 B.C. to the time of Christ; (*c*) from the time of Christ to that of Roger Bacon (approximately 1300 A.D.); (*d*) from 1300 A.D. to 1800 A.D.; (*e*) from 1800 to modern times.

2. Discuss the following statements, or generalizations,[1] in class to discover whether you agree or disagree with them. Choose one or more of them as a subject for a composition in your English class.

a. The work now being done in factories, mills, laundries, and so on is in general a substitute for work formerly done on farms and in homes.

b. Women no longer spend as much time in caring for children, because of their increased employment in the industries.

c. The world is a better place to live in now than one hundred years ago; one thousand years ago.

d. Scientific discoveries and advances of modern times have made special services available for the betterment of health.

e. Because of scientific progress, people now have more time for leisure activities, cultural advantages, and education than at the time of their grandparents.

f. At the present time more young people, upon finishing their education, find jobs in service occupations, such as teaching, music, medicine, exploring, nursing, writing, acting, and art, because science has made it easier for man to produce the necessities of life.

g. Scientific progress has brought about the building of big cities, thus crowding people together, and so has changed living conditions for millions.

h. Some of the changes brought about by science have been detrimental to the health and happiness of people.

i. Dense populations brought about by our scientific civilization have tended to make disease and crime very difficult to control.

j. Material progress has brought about the exploitation of natural resources and has made conservation laws necessary.

3. Read the chapter or chapters devoted to the subject of the impact of science on our lives or to related subjects in any of the books listed in the following "References for Further Reading," and from this reading evolve for yourself two generalizations like those given in Problem 2 above.

4. List several commonly used articles or materials which you believe have contributed most to your enjoyment of living. Try to describe the part that chemistry has played in making these articles possible.

5. Compare everyday living with and without the following chemical substances: (*a*) anesthetics, (*b*) coal-tar dyes, (*c*) rubber, (*d*) paint, (*e*) cosmetics, (*f*) steel.

6. Describe medical practices before the time of Pasteur and compare them with medical practices today.

7. Present a report to the class on the life of Pasteur and of Lister.

8. Why is the food we eat today better for health than the food of one hundred years ago?

9. What are some of the newest articles and substances which are products of chemical industries? How have they improved living?

10. Tell what you expect to get from a study of chemistry.

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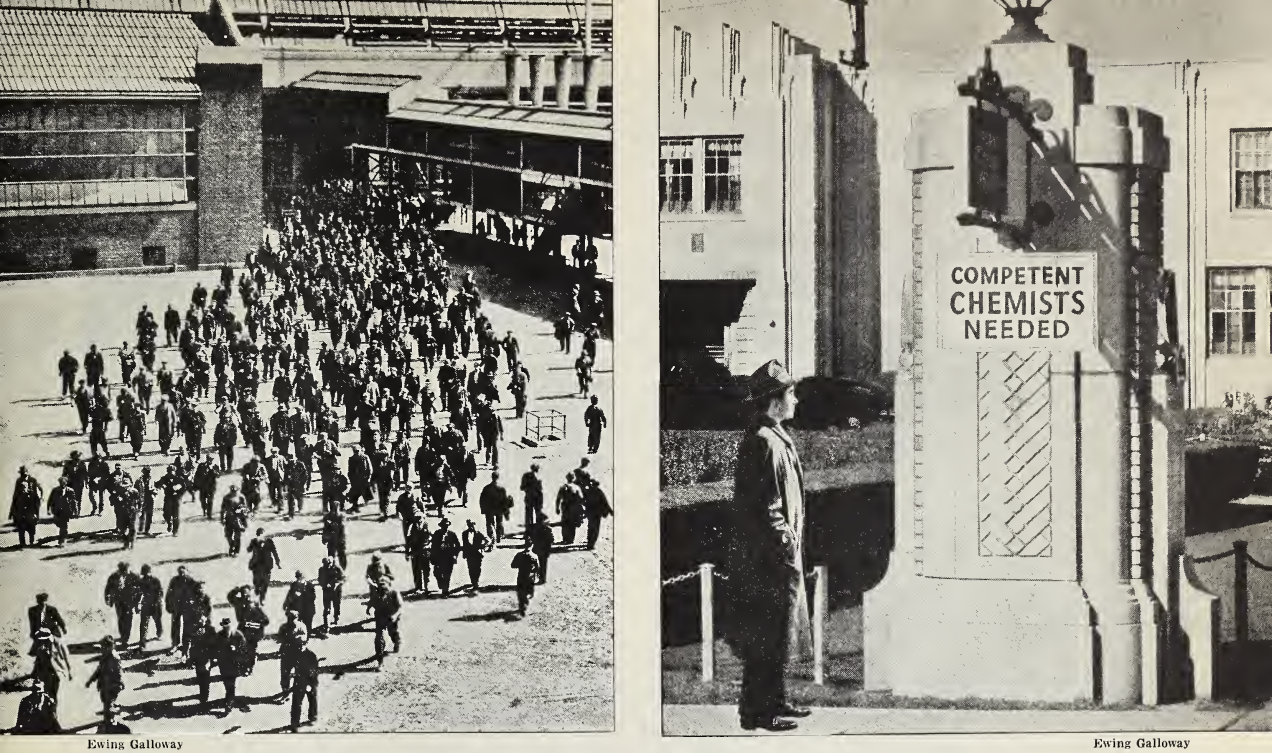
[1] Many of these statements were taken from *Science in General Education*, a publication of the Progressive Education Association.



Ewing Galloway

Ewing Galloway

Industry provides a livelihood for thousands of our people, enabling them to maintain a good standard of living

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REFERENCES FOR FURTHER READING

Arrhenius, Svante. *Chemistry in Modern Life.* D. Van Nostrand Company, Inc., New York, 1925.

Borth, Christy. *Pioneers of Plenty.* The Bobbs-Merrill Company, New York, 1939.

Bunzell, H. H. *Everyday with Chemistry.* Grosset & Dunlap, Inc., New York, 1937.

de Kruif, Paul. *Microbe Hunters.* Harcourt, Brace and Company, New York, 1932.

de Kruif, Paul. *Men against Death.* Harcourt, Brace and Company, New York, 1933.

Furnas, C. C. *The Next Hundred Years.* The Williams & Wilkins Company, Baltimore, 1936.

Haggard, Howard Wilcox. *Devils, Drugs, and Doctors.* Harper & Brothers, New York, 1929.

Hessell, F. A., Hessell, M. S., and Martin, Wellford. *Chemistry in Warfare.* Hastings House, New York, 1940.

Holmes, Harry N. *Out of the Test Tube.* Ray Long & Richard R. Smith, New York, 1937.

Howe, H. E. (Editor). *Chemistry in Industry* (2 vols.). The Chemical Foundation, Inc., New York, 1924–1925.

Jaffe, Bernard. *Crucibles.* Tudor Publishing Company, New York, 1934.

Kelley, F. C. *One Thing Leads to Another.* Houghton Mifflin Company, Boston, 1936.

Martin, Geoffrey. *Triumphs and Wonders of Modern Chemistry.* D. Van Nostrand Company, Inc., New York, 1932.

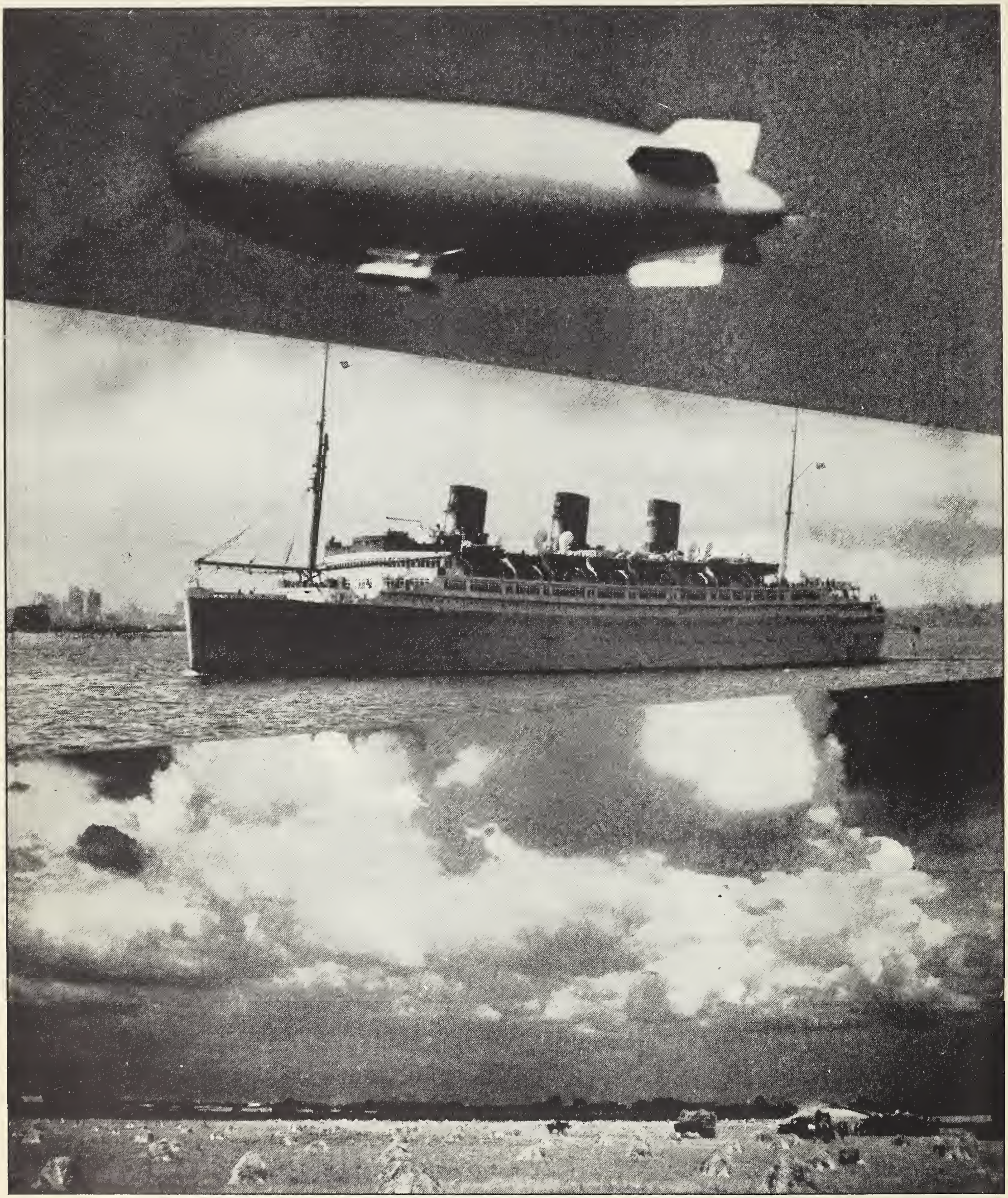
Moore, F. J. *A History of Chemistry.* McGraw-Hill Book Company, Inc., New York, 1918.

Morrison, A. Cressy. *Man In a Chemical World.* Charles Scribner's Sons, New York, 1937.

Slosson, E. E. *Creative Chemistry.* D. Appleton-Century Company, Inc., New York, 1919.

Vallery-Radot, René. *The Life of Pasteur.* Garden City Publishing Company, Inc., New York, 1937.

Wells, H. G. *The Outline of History.* Garden City Publishing Company, Inc., New York, 1930.



Ewing Galloway

The helium in the dirigible, the water vapor in the clouds, the ship on the ocean, the earth, the air, and all things which have weight and occupy space are matter

The Material World: Matter

Can you imagine anyone making counterfeit pennies out of gold? This may seem absurd, but the early Spaniards actually made counterfeit silver-colored coins out of the now more valuable metal platinum. When the Spanish first explored Panama in Central America, they discovered platinum along with the silver which was mined there. Silver was very valuable because it was rare and because, through centuries of use, its properties were well known. Little was known of the properties of the much harder metal platinum, and it was considered worthless. Consequently unscrupulous men made counterfeit coins of platinum. A few of these now almost priceless coins are in museums. Platinum today is a very valuable and useful metal, not only because it is rare, but because of its properties. These properties make platinum widely used in modern industry. What has been true of platinum is also true of many other kinds of matter. As the properties become known, the materials are rendered more useful to us.

In this unit you will study many of the properties of matter which determine its usefulness in the home and in the industrial world. If you are to get the maximum value from the many appliances about your home, from the food you eat, the clothes you wear, and the many other articles you use, you should know something of the properties of matter. In order to have a better understanding of these properties, you should have some knowledge of how the chemist classifies matter. Knowing this, you can read scientific articles and books with better understanding. Moreover, from the study of this unit you should get a broad, general picture of the things that make up the world about you.

PURPOSES TO BE ACHIEVED

1. To understand the nature of matter.
2. To gain an appreciation of the definiteness and orderliness of matter.
3. To understand how the scientific method of thinking has been used in gaining a better knowledge of the nature of matter.
4. To learn how to identify matter.
5. To gain a general understanding of the importance of chemical change in the transition of one substance into another.

PROBLEMS TO BE SOLVED

1. What is matter and how do you recognize it?
2. What is the composition of matter?
3. What determines the purity of matter?
4. What changes does matter undergo?

Problem 1. What is matter and how do you recognize it?

Definition of matter. As you look about the room, all the objects which you see are composed of matter. The chair in which you sit, the glass in the window through which you look, the water you drink, and even the air you breathe are examples of matter. All these things *occupy space and have weight.* Such characteristics as those of occupying space and having weight are called the properties of matter. There are many kinds of matter, the different kinds being called substances. Each substance is recognized by its own set of properties, or characteristics.

How do you recognize matter? There are many properties which are peculiar to different material objects. If you describe a piece of glass, a metal cylinder, or water in a pitcher, you will find that you are describing it by its properties. Try it. These substances are quite different, and you have no difficulty in distinguishing them by casual observation. However, if you were to compare a chromium cylinder and a nickel cylinder, you would have more difficulty. You would recognize that they are metals because of their peculiar metallic luster, that they are both hard, and, since they are

How could you prove by these experiments that air occupies space?

good conductors of heat, that they feel cool to the hands. But how could you be sure which of the shiny metal cylinders was nickel?

The scientist is never convinced by casual observation. He would make various tests to find out the exact properties of the metals in the cylinders before he identified them. In doing this, he would be using the scientific method.

What are physical properties and chemical properties? If you attempt to identify substances, you will immediately find that there are two kinds of properties that they may possess. One of these is physical, while the other is chemical. If we say a substance is heavy or white, or that it melts readily, we are describing the characteristics of its physical nature. Examine some red phosphorus and describe it to the class. Undoubtedly you will describe red phosphorus by the characteristics that it has just as it is, without undergoing any change. It is a red powder, heavier than water, and has no odor. These are physical properties of red phosphorus. You usually recognize common things by their physical properties.

Chemical properties have to do with the behavior of substances. Place an amount of red phosphorus, the size of a pea, on an asbestos mat and touch it with a hot metal rod. It begins to burn, and a white smoke is given off. Gradually all the red phosphorus disappears. Obviously, a new material has been formed with new properties. We say, then, that red phosphorus is inactive at ordinary temperatures in air, but becomes active if the temperature is increased to a certain point. This experiment shows some of the chemical properties of red phosphorus. As you study this unit, you will more clearly understand the difference between the physical properties and the chemical properties of different substances.

Physical properties by which you may identify a substance. It is often possible to identify a substance, provided it is pure, by one or more of its physical properties. Since most substances are impure, the scientist may wish to determine the exact composition of a substance before attempting to identify it. However, for practical, quick determination of what a substance is, many chemists depend upon its physical properties. Let us now discuss some of these physical properties so that you may have a better understanding of matter.

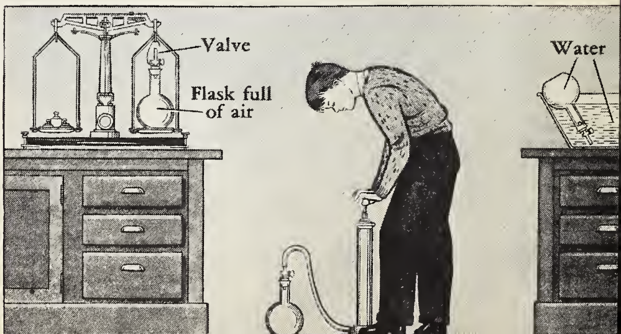
States of matter. In what form is a piece of ice? If it is heated, it changes to the common form of water; and if the water from the ice is heated to a higher temperature, it changes into steam. All matter exists in one of these three states, *solid, liquid,* or *gas.* Can you name other substances which can be changed from one physical state to another?

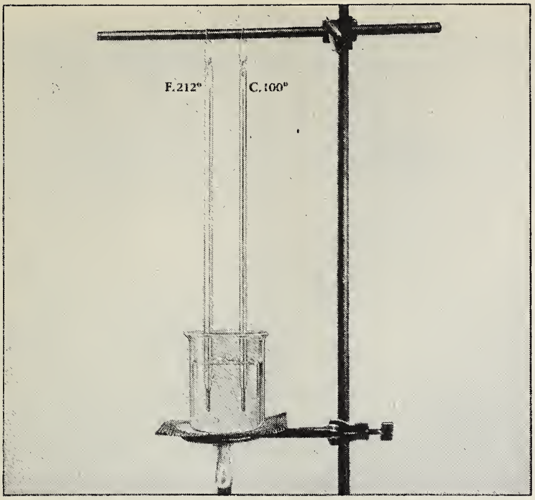
Liquids take the form of the containing vessel, while a solid has a form of its own. Gases have no definite form, or shape.

Many pure substances have definite temperatures at which they change from one physical state to another, and may be identified in this way. The melting point of pure ice (water) is 0° centigrade (C), or 32° Fahrenheit (F). Its boiling point at sea level is 100° C, or 212° F. Pure alcohol boils at 78° C under similar conditions. The centigrade scale for measuring temperatures is generally used in scientific work. The method of converting a temperature of one scale to that of another is given in the Appendix of this book.

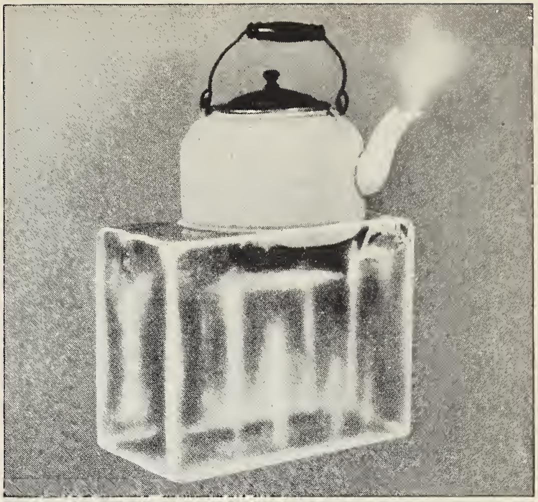
Density. Suppose you had two metal cylinders of equal volume, one nickel and the other chromium. You could distinguish one from the other by weighing each. Since it is known that a certain volume of nickel is heavier than an equal volume of chromium, the heavier cylinder must be nickel.

How could you use the apparatus shown in this picture to prove that air has weight?





At sea level water boils at 100° C, or 212° F. Under what conditions would the boiling temperature be increased or decreased?

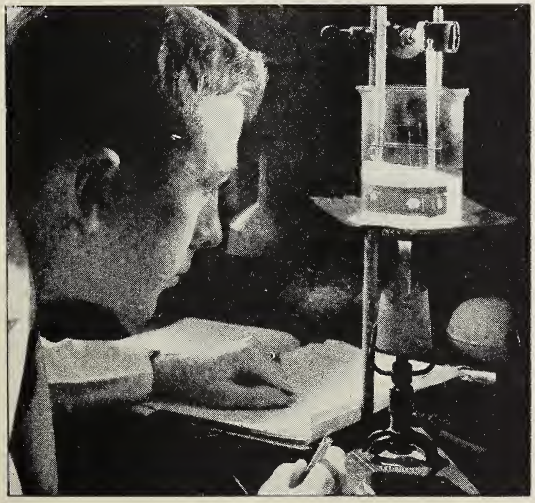


This teakettle contains liquid air which is boiling on a block of ice. Why does the ice act as a stove in boiling liquid air? What states of matter are represented in this picture?

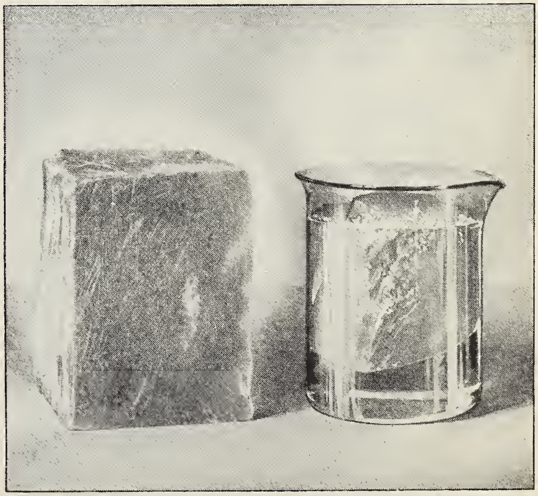
How does the scientist know that nickel is a heavier metal than chromium? To answer this question he must compare accurately the weights of these metals. For this purpose, it is necessary to use equal volumes of the metals.

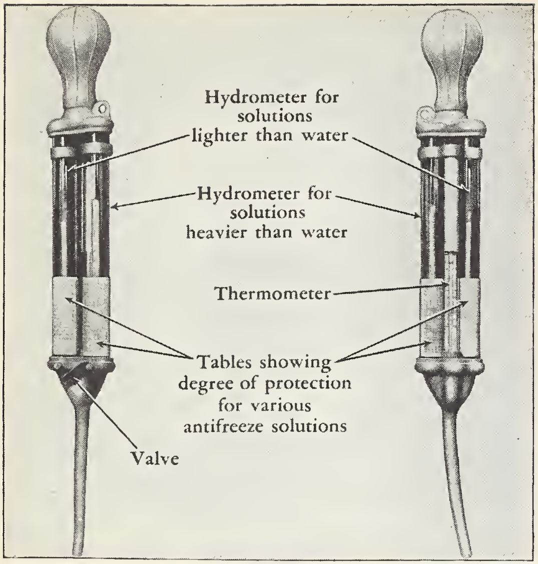
When the scientist compares the weights of equal volumes of different substances, he is comparing their *densities*. The density of a substance is determined by finding the weight of a unit volume of the substance. In determining the density of a substance in the metric system, the volume is expressed in cubic centimeters and its weight is expressed in grams. *Density is the weight in grams of one cubic centimeter of a substance.*

The melting point of ice is 0° on the centigrade scale and 32° on the Fahrenheit scale



When "Dry Ice" is placed in water, the change from solidified carbon dioxide to gaseous carbon dioxide is evident. Why does this change in the state of matter take place so rapidly?




Hydrometer for solutions lighter than water
Hydrometer for solutions heavier than water
Thermometer
Tables showing degree of protection for various antifreeze solutions
Valve

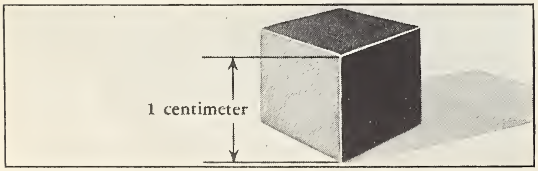
Ford Motor Company

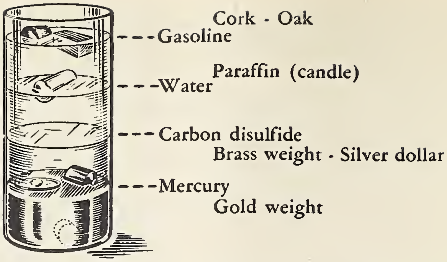
This modern hydrometer is used to find the specific gravity of commonly used liquids, such as antifreeze solutions

The densities of all common materials have been determined, and the most important density for you to remember is that of water. Since 1 cubic centimeter (abbreviated cc) of water weighs 1 gram (abbreviated g), its density is 1 gram per cubic centimeter.

Another term frequently used is *specific gravity*, which is the ratio of the weight of any volume of a substance to the weight of an equal volume of water. Since the density of water is 1 gram per cubic centimeter, the specific gravity in the metric system is numerically equal to the density of a substance. To illustrate, the density of iron is 7.8 grams per cubic centimeter. Since the ratio of that weight to the weight of 1 cubic centimeter of water is 7.8 to 1, the specific gravity of iron is 7.8. Thus we mean that iron is 7.8 times as heavy as water.

This piece of iron weighs 7.8 grams. What is its density?





Explain why the various objects shown in this illustration are floating at different levels

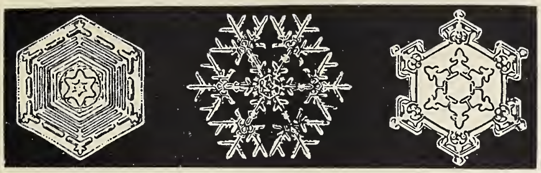
Look at the first table below and see if you would have placed the most common metals in about the places in which they appear in the table. Should you have imagined that aluminum would be high in the table, while lead is near the bottom? A number of questions may come to your mind regarding density. Why does wood float on water? Why does cream rise in milk? Is cream more dense than milk? Find the answer to these questions by observation or by consulting these tables of densities:

Density of Some Metals

	Grams per Cubic Centimeter		Grams per Cubic Centimeter
Lithium	.534	Nickel	8.8
Potassium	.86	Copper	8.9
Sodium	.97	Silver	10.5
Calcium	1.55	Lead	11.3
Aluminum	2.70	Mercury	13.6
Chromium	6.52	Gold	19.3
Zinc	7.1	Platinum	21.5
Tin	7.3	Osmium	22.5
Iron	7.8		

Density of Other Substances

	Grams per Cubic Centimeter		Grams per Cubic Centimeter
Asbestos	2.0	Leather	.86
Bone	1.7	Limestone	2.7
Butter	.86	Milk	1.032
Carbon tetrachloride	1.59	Resin	1.07
Carbon disulfide	1.26	Salt, rock	2.1
Cement	2.7	Starch	1.53
Clay	1.8	Sugar	1.61
Coal	1.5	Talc	2.7
Cork	.22	Tallow	.9
Gelatin	1.27	Wood, bamboo	.31
Glass	2.5	Wood, ebony	1.11
Glue	1.27	Wood, oak	.60
Ice	.91	Wood, yellow pine	.37



Snow crystals always exist in a hexagonal pattern, but no two are exactly alike

Since the densities in the preceding tables are expressed in metric units, the numbers are numerically the same as the specific gravities of the various substances.

Crystalline and amorphous substances. Have you ever examined a snowflake on the sleeve of your coat in the winter? Did you ever notice its regular starlike form? Many substances exist in a definite form, some as cubes, some as long needles, and some with many faces, or sides. Substances which exist naturally in definite shapes are said to be *crystalline.* Since metals are made up of minute crystals, the scientist may identify a metal by breaking a piece of it and examining it under a microscope. This brings out the structure of the crystals, and thus it may be identified. Many chemicals may be identified in this manner in the laboratory.

The molecules of such substances as flour, rubber, and wool are not grouped together in the form of crystals. Therefore these substances are said to be *amorphous.* Can you name other substances of this class?

Conduction of heat. Have you ever been the unfortunate person on a picnic who got the coffee cup made of aluminum, while the others about you got the porcelain cups? If you have, you know how the aluminum cup burned your lips and fingers, while the users of the porcelain cups seemed to feel no discomfort. Aluminum conducts heat much better than porcelain or other nonmetals. Good conduction of heat is a physical characteristic of all metals. The scientist is not satisfied with knowing merely this fact; he wants to know just how well the different substances conduct heat. Could you suggest a way to determine whether a wire was iron or nickel by this property? Refer to the illustration at the right.

Conduction of electricity. Have you ever wondered why most of the electric wires are made of copper instead of the cheaper metal iron? There are several reasons for this; perhaps you can give some of them. One important reason is that copper conducts electricity much better than iron. All metals conduct electricity, and by this means we can often tell whether a substance is a metal, though not always, as we shall see later. However, the scientist has been able to arrange the metals in a table according to the ease with which they allow the electric current to flow.

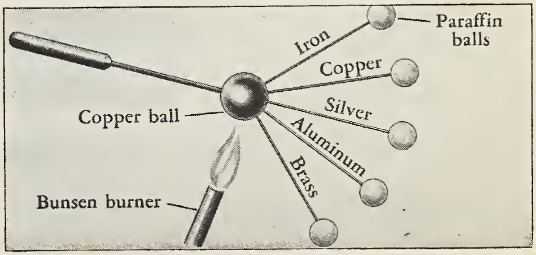
Hardness. Substances may be graded as to their hardness on a scale from 1 to 10. Talc, the principal ingredient of talcum powder, may be scratched with the fingernail and has a hardness of 1, whereas the diamond has a hardness of 10. How could you prove the diamond harder than glass? The hardness of the basic ingredient in tooth paste determines its scouring, or scratching, effect upon the teeth.

Chemical properties also aid in the determination of the nature of a substance. It is well known that iron rusts and silver tarnishes, while gold remains bright. This chemical property of the rusting or tarnishing of a metal is known as corrosion. Many metals may be distinguished one from another by the ease with which they corrode.

When a substance corrodes, we can see that a new material has been formed. The new substance has different properties. When we study the ease with which a metal corrodes, or changes into a new substance, we are studying one of the chemical properties of that substance. In your study of chemistry you will learn a great deal about other chemical properties of many materials.

You have learned in this problem that every

How can the rate of heat conductivity of metals be determined by the use of this apparatus?



substance has certain chemical and physical properties peculiar to it. The physical properties, such as the physical state, density, definiteness or indefiniteness of structure, conduction of heat and electricity, and hardness aid in identifying substances. Often the color of a substance, its luster, or even the conditions under which it is found give clues to its identity. Very often, however, a substance is complex in composition, and only analysis of its chemical nature gives evidence of its true identity. The scientist never guesses; he must have positive proof of the nature of a substance before he is sure of its identity.

Closely related to matter are the forces of nature which act upon matter. You will study the relationship between matter and these forces in the next unit.

EXERCISES

The following statements are incomplete. On a separate piece of paper write whatever is necessary. Do not write in this book.

1. When we say that iron is gray and hard, and has a density of 7.8 grams per cubic centimeter, we are describing one of its --(?)-- properties.

2. When we say that iron rusts readily, we are describing a --(?)-- property of it.

3. The boiling point of alcohol is 78° C. Its boiling point on the Fahrenheit scale is --(?)--. (See Appendix.)

4. Liquid oxygen boils at 185° below zero centigrade (−185° C). Its boiling point on the Fahrenheit scale is --(?)--.

5. Pure lead melts at 620.6° F or --(?)-- ° C.

6. If 25 cubic centimeters of a liquid weighs 36 grams, its density is --(?)--.

7. If the specific gravity of a metal is 19.3, then 10 cubic centimeters of it will weigh --(?)-- grams.

8. If an irregular piece of iron weighs 4056 grams, its volume is --(?)-- cubic centimeters.

9. Since starch is powdered and has no definite form, it is said to be --(?)--.

10. What metal will sink in water but will float in carbon tetrachloride?

11. Anything that has weight and occupies space is called --(?)--.

12. Materials are identified by their --(?)-- or --(?)-- properties.

13. Chemists depend upon --(?)--, in addition to physical properties, to identify a substance.

14. List the physical properties which would enable you to distinguish a piece of silver from a piece of iron.

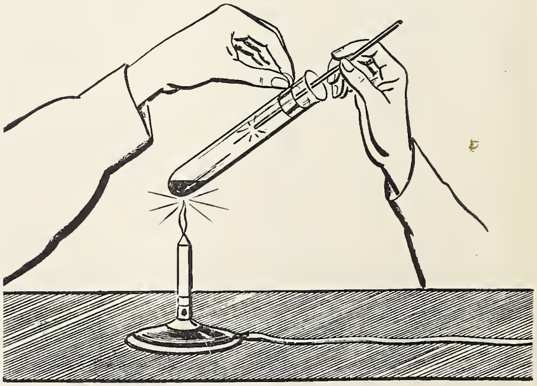
15. Most kinds of matter may be made to exist in the --(?)--, --(?)--, or --(?)-- state.

16. Make a list of five gaseous substances, five liquid substances, and ten solid substances.

Problem 2. What is the composition of matter?

The simplest kinds of matter — elements. In 1774 Joseph Priestley, an Englishman, heated a substance known to him as mercuric ash and obtained mercury and oxygen. But however hard he might have tried, he could not have broken the mercury or oxygen down into simpler substances. Such substances as mercury and oxygen, which contain only one kind of matter, are called *elements.* Other familiar elements are iron, sulfur, and carbon. Look at the table of elements in the back of the book and see how many there are with which you are familiar. At present there are 92 elements known to exist in nature. These are the building blocks of the universe. The story of how some of them were discovered is fascinating. Look up the story of how helium was discovered on the sun and then on the earth. You will enjoy reading about Madame Curie and her discovery of radium, or about the work of Sir William Ramsay on the elements in the atmosphere. A list of references on the discovery of the elements is given at the close of this unit.

This experiment is similar to the one performed by Priestley in decomposing mercuric oxide. What is the purpose of the glowing splint?



Atoms—the smallest particles of elements. If you should break a piece of the element iron, you would have two pieces of iron, each with identical properties. If you keep dividing each part into smaller particles, you will eventually arrive at a particle which you cannot divide and still have iron. Such a particle would be called an atom of iron.

The atoms of any element are alike in their properties. In general, the atoms of a particular element weigh the same, but the atoms of different elements have different weights. Actually there is a slight variation in the weights of the atoms of some elements. These atoms of an element that differ in weight are called isotopes. In all other respects than weight isotopes have the same properties.

The size of atoms. Do you think you could see an atom with the naked eye? with a microscope? Dr. W. R. Whitney, a distinguished American scientist, makes this statement regarding the size of atoms: "There are so many atoms of hydrogen in one drop of water that if the atoms were as big as the drop they would cover the whole earth with one foot of water." An idea of the very minute size of the atom may be gained also from this fact: One ounce of hydrogen contains 168,000,000,000,000,000,000 atoms. From these facts, it is evident that the atom is so small that it cannot be seen with the aid of the most powerful microscope.

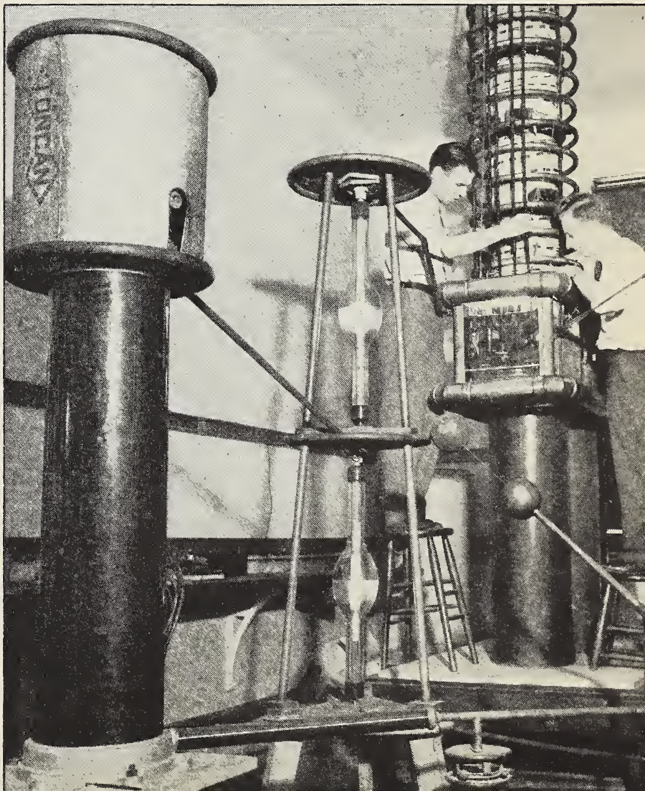
What are atomic weights? Since atoms are exceedingly minute, they weigh very little. The weight of an oxygen atom has been calculated to be 0.000000000000000000000026 gram. Since this number is so small, it is a difficult one to use. Therefore chemists use a simpler system—a system of relative weights called atomic weights. This system is based upon the oxygen atom because oxygen unites with more elements than any other element. The atomic weight of oxygen is used as the standard of this system. Hydrogen is the lightest of all the atoms; its weight is about $\frac{1}{16}$ that of the oxygen atom. In order that hydrogen may have a weight of approximately 1, oxygen is taken as 16. This means that an atom of oxygen weighs 16 times as much as hydrogen. If an atom of oxygen has a weight of 16, an atom of nitrogen will have a weight of 14 because it is $\frac{7}{8}$ as heavy as oxygen. The sulfur atom will have an atomic weight of 32. These weights are only approximate, with the exception of that of oxygen, and are called the *atomic weights* of the elements. You will find the atomic weights of the most common elements given in a table in the Appendix, at the back of the book.

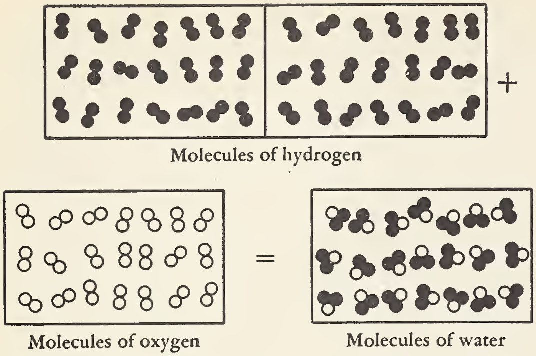
Chemists use these atomic weights very often in the calculation of formulas for medicines, synthetic rubber, plastics, and other industrial products. Even for such a simple process as that of cakemaking, a food chemist must depend upon the use of atomic weights to determine the proper amount of baking powder which must be added to the other ingredients. In all such processes accuracy and economy require the use of atomic and molecular weights.

Compounds contain different kinds of elements. You will recall that Priestley, in his classic experiment, heated "mercuric ash" and obtained oxygen and mercury (see page 22). Later he heated mercury,

It has been recently discovered that through the use of this atom-smashing machine, which employs high-voltage electric discharges, atoms of heavy elements may be changed to atoms of lighter elements. This machine may be used to change common table salt into a substance having properties similar to those of radium. This radioactive salt is now being used in the treatment of cancer

International News Photo





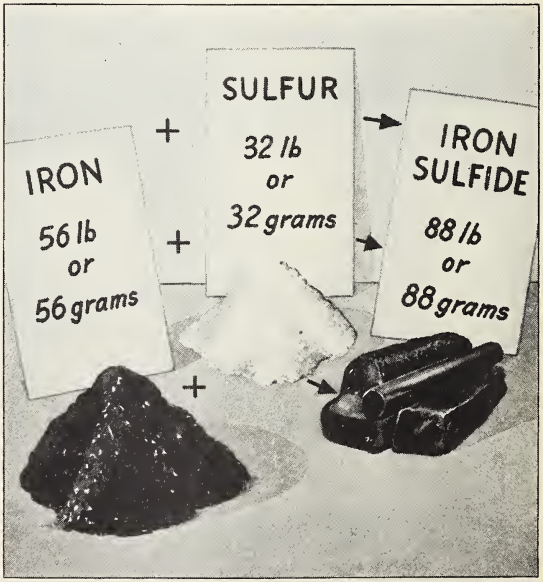
When molecules of hydrogen unite with molecules of oxygen, molecules of water (a compound) are formed

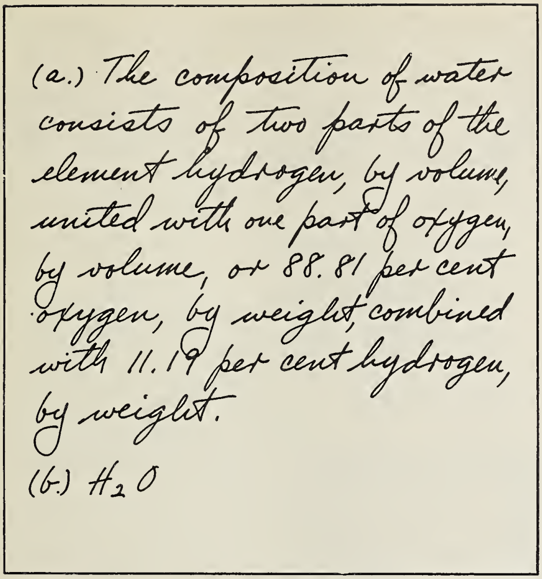
at a much lower temperature than he used in the first experiment, in a stream of air and discovered that the oxygen of the air combined with the mercury atoms to form a red powder, which we now call mercuric oxide. This red powder has properties entirely different from those of either of the elements from which it is made. The smallest particle of this new substance that can exist, and still have all the properties of the substance, must contain atoms of mercury and oxygen combined with each other. This small particle is called a *molecule*, and the new substance is called a *compound*. Molecules are small particles of matter containing two or more atoms. The atoms of a molecule may be of the same element or of different elements. A compound is a substance produced by the chemical union of two or more different elements. Salt and sugar are examples of compounds, and the smallest particle of each of these compounds which has all the properties of that compound is the molecule.

There are always a definite number of atoms of each element in one molecule of a compound, and, since each of the atoms has a definite weight, the molecule of the compound also has a definite weight. This is called the *molecular weight* of the compound. *Every compound consists of two or more elements united chemically in definite proportions by weight.* This is called the *law of definite composition.* Thus every molecule of ordinary water is made up of two atoms of hydrogen united with one atom of oxygen, whether the water is in the China Sea or in the glass of water on your table. In a molecule of water there are eight parts of oxygen to one part of hydrogen by weight. The composition of pure ice and steam is the same as that of pure water because when a physical change takes place in matter, there is no change in the structure of the molecule.

What is the chemist's shorthand? The chemist shows the chemical composition of water when he writes H_2O. What do the letters represent? What does the figure 2 stand for? The letters H and O are symbols for the elements hydrogen and oxygen. The figure 2, called a subscript, indicates that a molecule of water contains two hydrogen atoms. As the oxygen has no subscript, the water molecule contains only one oxygen atom. A formula, such as H_2O, shows the composition of one molecule of a compound. You will learn the formulas for many compounds in chemistry. A formula is the chemist's shorthand method of telling what elements make up the molecule of a compound. A formula is qualitative because it tells you what is in the compound and quantitative in that it tells you how many atoms of each element compose each molecule. The formula for limestone is $CaCO_3$. What elements compose it?

This picture illustrates the law of definite composition. For example, iron and sulfur combine in a definite ratio to form iron sulfide. What is the ratio? Does it ever change?





(a.) The composition of water consists of two parts of the element hydrogen, by volume, united with one part of oxygen, by volume, or 88.81 per cent oxygen, by weight, combined with 11.19 per cent hydrogen, by weight.

(b.) H_2O

A comparison of the longhand method and the chemist's "shorthand" method of writing the formula of water

You should know the names of common elements and the symbols used by chemists to represent them. The elements and symbols listed in the following table should be thoroughly studied:

Common Elements and Their Symbols

Aluminum	Al	Lithium	Li
Antimony	Sb	Magnesium	Mg
Arsenic	As	Manganese	Mn
Barium	Ba	Mercury	Hg
Bismuth	Bi	Molybdenum	Mo
Boron	B	Nickel	Ni
Bromine	Br	Nitrogen	N
Cadmium	Cd	Oxygen	O
Calcium	Ca	Phosphorus	P
Carbon	C	Platinum	Pt
Chlorine	Cl	Potassium	K
Chromium	Cr	Radium	Ra
Cobalt	Co	Silicon	Si
Copper	Cu	Silver	Ag
Fluorine	F	Sodium	Na
Gold	Au	Strontium	Sr
Helium	He	Sulfur	S
Hydrogen	H	Tin	Sn
Iodine	I	Tungsten	W
Iron	Fe	Vanadium	V
Lead	Pb	Zinc	Zn

EXERCISE

Copy on a sheet of paper the formulas of the common substances listed below. Write beside each one the names of the elements in each compound and the number of atoms of each element found in one molecule of each compound.

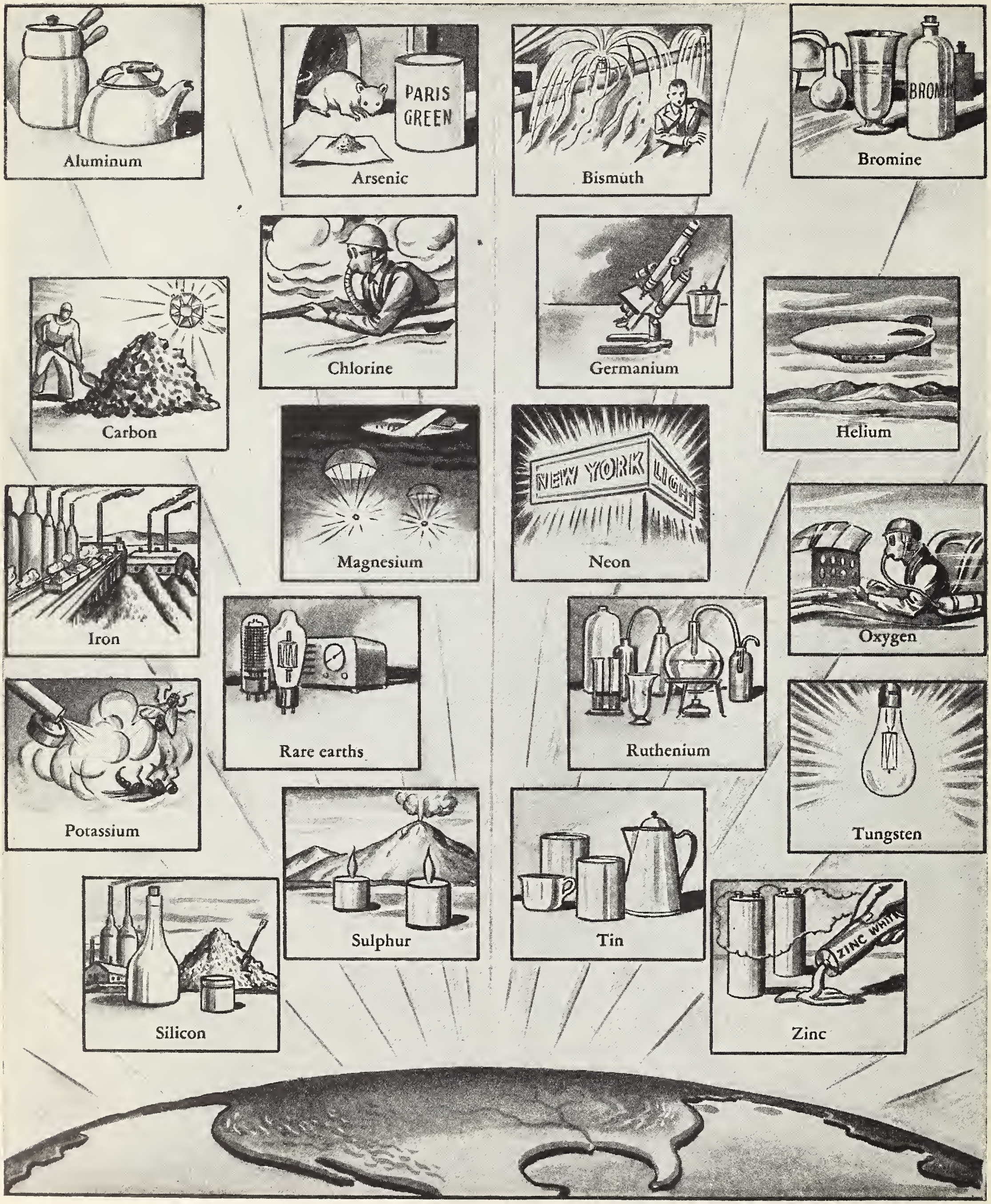
Table salt, $NaCl$; sand, SiO_2; carbon dioxide ("Dry Ice"), CO_2; sugar, $C_{12}H_{22}O_{11}$; the acid in vinegar (acetic acid), $HC_2H_3O_2$; soap, $C_{17}H_{35}COONa$; natural gas (methane), CH_4; chloroform, $CHCl_3$; turpentine, $C_{10}H_{16}$; baking soda, $NaHCO_3$; limestone, $CaCO_3$; boric acid, H_3BO_3.

Problem 3. What determines the purity of matter?

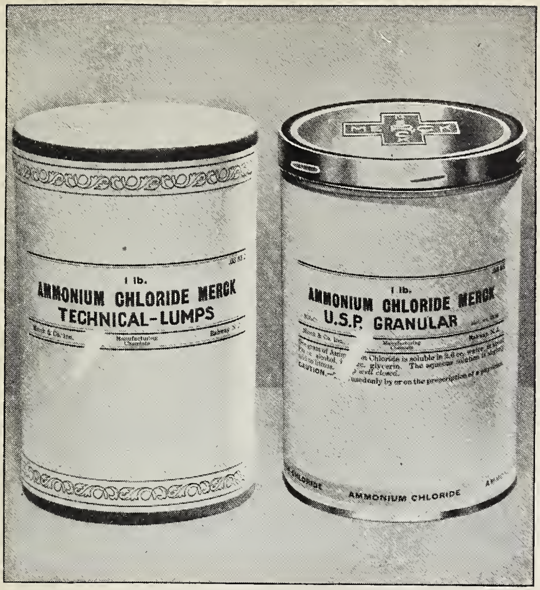
Mixtures and pure substances. If you should stir some salt and sand together, you would have two substances mixed together. This is called a *mixture*, since each of the substances retains its own properties. If you examine this mixture under a microscope, you can see the particles of sand and the crystals of salt. You would not have to put the two together in any definite proportion to have a mixture.

When salt is examined alone, it is found to contain only one kind of substance. Every particle of salt exhibits the same properties as every other particle of salt, both chemically and physically. If table salt is analyzed in the laboratory, every molecule will be found to contain one atom of sodium combined chemically with one atom of chlorine. The formula for salt, then, is $NaCl$. Salt is classed as a pure substance, since it contains only one kind of matter. Sulfur, sugar, and rainwater are examples of pure substances with which you are familiar.

Terms used to describe the purity of a substance. The term *pure substance* is likely to mislead you, since a substance is rarely ever free of all impurities. The term *pure*, then, is only a relative term and indicates that very little foreign substance is present. A chemically pure substance is one from which most of the impurities have been removed. Examine some of the chemical, or reagent, bottles in the laboratory stock room or on the laboratory reagent rack. You will probably find some chemicals labeled "Reagent Grade" and others labeled with "C.P." after the names of the chemicals. The highest grade of chemicals sold by most companies



Important uses of some of the most common elements. Can you give other uses for each element?



How can the difference in the purity of chemicals be determined by the labels?

is classified as "Reagent Grade." This grade conforms in most cases to American Chemical Society specifications. C.P. stands for the words *chemically pure*. However, these labels do not mean that there are no impurities in a reagent. Different chemical manufacturers have different standards of purity. We are to suppose merely that the substance is relatively high in purity. The abbreviation *Tech.* means that a substance is technically pure, that is, that the amount of impurities is small and that for many purposes the substance will do as well as those marked "C.P." Many chemicals and drugs will sometimes have on the label the abbreviation *U.S.P.*, which means that the substance meets the high standards of the United States Pharmaceutical Association. Materials which have this label can be depended upon to be of high purity. Sometimes the abbreviation *Com'l* ("commercial") appears after the name of a chemical. Such chemicals are usually considerably cheaper than those of other grades, since they are often in the unpurified form. They may be used for many industrial purposes, however, since the impurities may have no effect upon the processes involved.

EXERCISES

1. Discuss the following substances in class to determine which are pure substances and which are mixtures:

Milk
Alcohol
Baking soda
Brass
Silver
Sand
Wood
Water
Coal
Lard
Perfume
Glass
Soil
Paper
Rubber
Sugar
Salt
Glycerin
Zinc ground with sulfur

2. Make a list of common substances about your home. Enumerate the uses of each substance on your list.

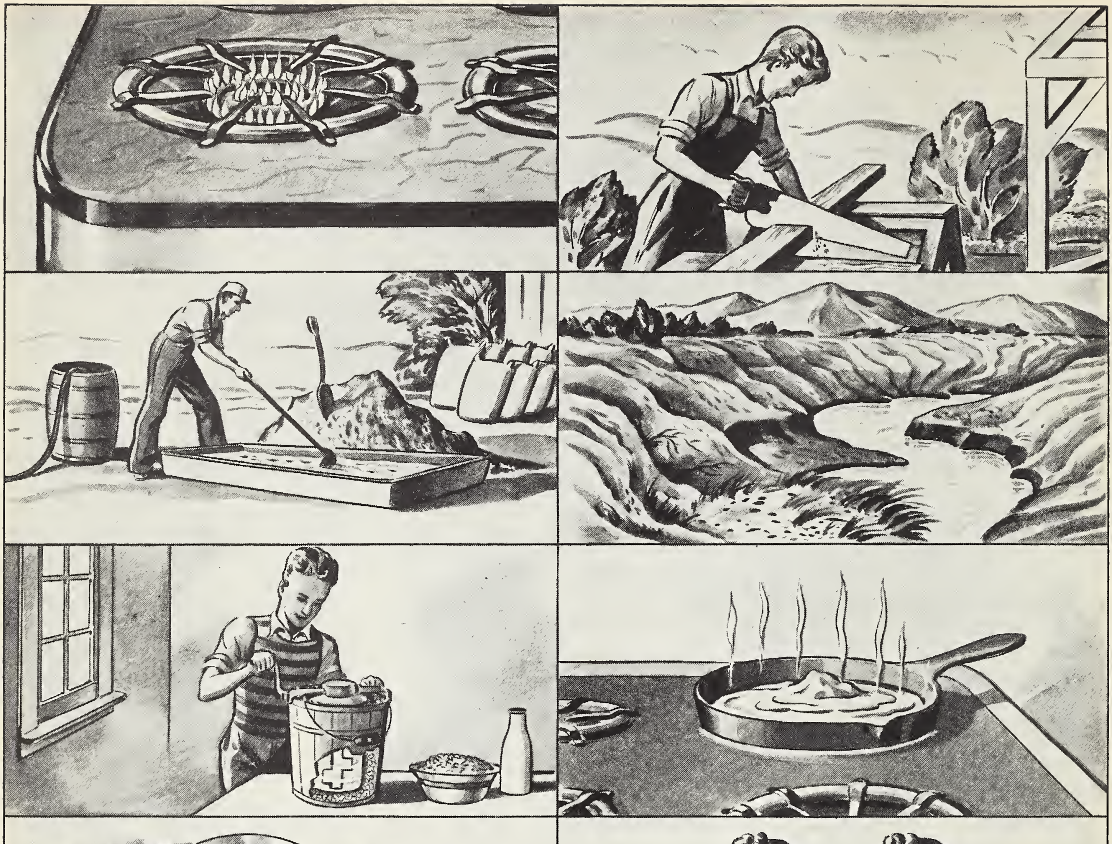
3. Copy the list of substances below and write beside each one the letter *E* if it is an element, the letter *C* if it is a compound, and the letter *M* if it is a mixture.

Copper
Iron
Salt
Carbon
Water
Chlorine gas
Sulfur
Benzene
Nitrogen
Oxygen
Silver
Steel
Coal
Arsenic
Sand
Paper
Gold
Water vapor
Lead
Iodine antiseptic
Gasoline
Sugar
Flour
Glass
Tobacco
Alcohol
Hydrogen
Wood
Soap
Coffee

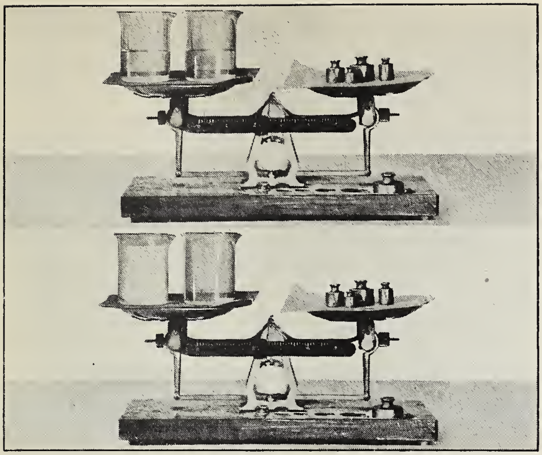
Problem 4. What changes does matter undergo?

Matter is continually undergoing changes in the world about us. The leaves change in color on the trees, fall to the ground, and decay. Rivers cut their channels deeper by grinding and dissolving the materials in their beds. Metals corrode when left exposed to the air, and forests are burned to the ground by fire.

Through research and experimentation man has made a study of the changes that matter may undergo, and has in many ways harnessed the forces of nature so that they do useful work. Most of our industrial world is based upon the principle of taking raw materials and, through changes, producing usable products. Because the changes are often very complex, it is sometimes impossible to tell the nature of the original substance unless you understand the process. Should you suspect that "Cellophane" was once a stately spruce tree or that the dye that is in your tie was once in a lump of black coal?



Common changes in matter which occur in everyday life.
Which changes are chemical, and which are physical?



When solutions of sodium chloride and silver nitrate are mixed, a white precipitate is formed. There is, however, no change in weight. Matter is neither created nor destroyed

Can man create matter? When Priestley heated mercury in the air, he found that the product weighed more than the original mercury. From this he reasoned that the additional weight must be due to the added oxygen. Later this conclusion was substantiated by the experiments of Lavoisier. The experiments of Priestley, Lavoisier, and many others prove that *matter can be neither created nor destroyed*, but may be changed into another form having different properties. This is called the law of conservation of matter.

When has a substance been changed? Should you still have chalk if you ground a piece of blackboard crayon into fine powder? Do you think the composition of wood has been changed by converting it into sawdust? Has the chemical nature of water been changed when it has been converted into steam? When we change the physical condition of a substance but do not alter the composition of the molecules that make up that substance, we say that a *physical change* has taken place. A substance may be changed from one physical form to another, and yet remain the same substance.

When atoms of different elements combine to form a new substance, as was the case when the mercury combined with the oxygen of the air in Priestley's experiment, or when a compound, such as mercuric oxide, breaks up into new substances having different properties, a *chemical change* has taken place. When metals corrode, a new substance has been formed, and, of course, a chemical change has taken place. There are two general types of chemical changes, one of which is called synthesis and the other decomposition. Would burning a piece of coal or wood be a chemical change?

When a new substance is prepared by combining simpler substances, we say that the new material has been made by *synthesis*. Thus a vegetable shortening compound is made by combining hydrogen with cottonseed oil. If a substance is broken down into simpler substances, we say that *decomposition* has taken place. For example, baking soda is decomposed into carbon dioxide and other substances during the baking of cake.

You will perform several experiments in the laboratory illustrating these types of changes in matter. Chemistry is the study of the changes that matter undergoes and of the ways in which man has taken advantage of this fact to produce many new and useful substances. Through his knowledge of chemical changes, man has been able to create artificially colors of the rainbow from coal, to change cornstarch into sirup, and from ores to produce metals that make the machines which do his work.

EXERCISE

Can you distinguish between common physical and chemical changes? Indicate the nature of the following changes by writing the numbers 1 through 11 on a separate sheet of paper and writing the word *physical* or *chemical* opposite each number:

1. The freezing of water.
2. The boiling of alcohol.
3. The decay of wood.
4. The burning of gasoline in a car.
5. The melting of sugar.
6. The tarnishing of a silver spoon by a rubber band.
7. The process of respiration.
8. The explosion of a firecracker.
9. The waxing of floors.
10. The growth of plants and animals.
11. The dissolving of salt in water.

UNIT EXERCISES

Which of the following statements are true and which are false? Do not write in this book; write on a separate sheet of paper. After taking the test, review the entire unit, check your answers, and correct those which are incorrect. Rewrite the false statements so that they will be true.

1. Substances which contain only one kind of matter are called elements.

2. Helium is an element.

3. Table salt is an element.

4. Man cannot destroy matter, but he can create matter.

5. When two or more elements combine chemically, a compound is formed.

6. The smallest particle of a compound which has all the properties of the compound is called a molecule.

7. Only through the most powerful microscopes can one see atoms.

8. A qualitative analysis of a substance tells you how much of each component is present.

9. When you buy a substance at a store and on the label is the statement that it is pure, you know that it contains no impurities.

10. Chemically pure reagents are those containing no impurities whatever.

11. When water boils, a chemical change takes place.

12. When iron is extracted from its ore, a chemical change takes place.

13. The composition of pure compounds always remains the same except in chemical changes.

14. When buying cascara sagrada for use as a laxative, the abbreviation *U.S.P.* on the label is a guarantee that it is of sufficient purity for internal use.

15. Priestley discovered oxygen during the latter part of the eighteenth century.

16. The most common scale of temperature measurement for use in America is the centigrade scale.

17. A cubic inch of mercury weighs more than a cubic inch of silver.

18. A platinum ring will float in mercury.

19. A silver ring will sink in mercury.

20. Pure water is a mixture.

21. Water is a mixture of the elements hydrogen and oxygen.

22. NH_4NO_3 contains one atom of nitrogen in each molecule.

23. The boiling point of water is the same on Pikes Peak as it is at sea level.

24. Boiling water is colder on top of Pikes Peak than at sea level.

25. The boiling point of a solution decreases as the altitude increases.

26. Absolutely pure substances are difficult to prepare.

27. Amorphous substances have definite crystalline structure.

28. Symbols and formulas are the chemist's shorthand.

29. Gasoline is a mixture.

30. Radium was discovered by Madame Curie.

31. All atoms of the same element have the same weight.

32. Oxygen is the lightest of all known elements.

33. The molecular weight of a compound is numerically equal to the sum of the weights of all the atoms which compose it.

34. Elements may be prepared by synthesis.

35. Rayon is a synthetic substance.

36. The element potassium is found in baking soda.

37. According to the law of definite composition, every molecule of table salt is like every other molecule of table salt.

38. When a house burns, matter has been destroyed.

39. The boiling of water is an example of a physical change.

40. A mixture is composed of two or more elements united chemically.

REFERENCES FOR FURTHER READING

CLARKE, BEVERLY L. *Marvels of Modern Chemistry.* Harper & Brothers, New York, 1932.

CURIE, EVE. *Madame Curie.* Doubleday, Doran & Company, Inc., New York, 1936.

FABRE, JEAN-HENRI. *The Wonder Book of Chemistry.* D. Appleton-Century Company, Inc., New York, 1923.

FISK, DOROTHY M. *Modern Alchemy.* D. Appleton-Century Company, Inc., New York, 1936.

FOSTER, WILLIAM. *The Romance of Chemistry.* D. Appleton-Century Company, Inc., New York, 1936.

JAFFE, BERNARD. *Crucibles.* Simon and Schuster, Inc., New York, 1930.

KENDALL, JAMES. *At Home among the Atoms.* D. Appleton-Century Company, Inc., New York, 1929.

UNIT 3

Forces at Work: Energy

Out in the desert of Nevada there stands a monument to the intelligence of man, a monument which will serve him for many years to come. Boulder Dam is the result of man's ability to apply his knowledge of the forces of nature. What is meant by the statement "Man harnesses the forces of nature"? For thousands of centuries the mighty Colorado River had spent all its energy in cutting deeper its path to the sea. The result is evident in the Grand Canyon of the Colorado, cut through walls of granite—nature pitted against itself. Because of man's imagination, he was able to convert this tremendous power from wasteful energy to useful work. Where the forces of the river had been previously spent against the walls of the canyon for miles, they are now largely concentrated at one point—against the blades of giant turbines. These turbines transform the energy of the moving water into electrical energy, which is used to light cities and farms hundreds of miles away and turn the wheels of industry. Man in this modern mechanical and chemical world needs power. In order to understand power, we must study the kinds of energy in nature. This unit deals with that study, and in it you will learn not only about the kinds of energy and how one kind may be transformed into another, but also about the relationship between matter and energy.

PURPOSES TO BE ACHIEVED

1. To understand some of the forces of nature that man may put to work.
2. To gain a better understanding of the relationship between matter and energy.
3. To learn how man may utilize the forces of nature to do his work.
4. To become aware of the fact that energy is definite and measurable.
5. To gain an appreciation of how the social and economic status of man is changed by his utilization of the forces of nature.

PROBLEMS TO BE SOLVED

1. What is the nature of molecular motion?
2. What is energy?
3. How may man transform and use energy?

Problem 1. What is the nature of molecular motion?

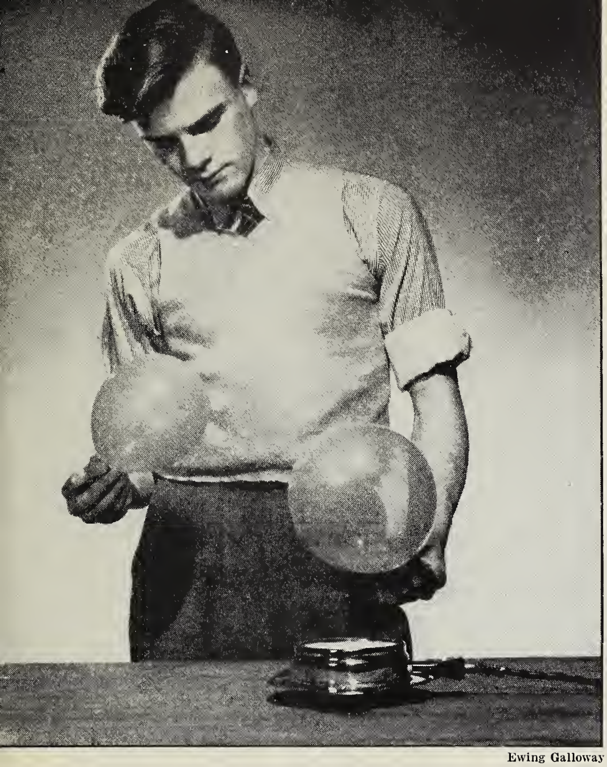
Dancing molecules. Though a molecule is very small, it is at the same time very active. If you should open a bottle of strong perfume in a room, the odor would soon be noticeable in every corner. Why is this so? *In every substance, whether a solid, a liquid, or a gas, the molecules are in a state of constant motion.* They are bounding and rebounding in every direction. Scientists have discovered that the motion of the molecules can be speeded up or retarded. If we heat a substance, the molecules move about much more rapidly, constantly increasing the distance between them, and therefore they move in a greater space. The amount of space in which the molecules move is much greater than the space which they actually occupy. It has been estimated that if all the molecules in an ordinary dining table were crowded together, with no space left between them or within them, the table would be so small as to be able to stand on the head of a pin.

If we hold a rubber balloon above a hot stove, its volume will be increased as it is heated. Since no more air has been added, the number of molecules must remain the same; only the space in which they move has increased. Could you prove that the amount of matter in the balloon remains the same? The distance between the molecules has increased because of the increased speed of each molecule, and therefore the balloon must expand. What has happened to the density of the gas?

Drop a crystal of potassium permanganate into a tall cylinder of water. Do not stir the water. If you will examine the cylinder a few hours later, you will find that the crystal has dissolved and the purple color has been extended to all parts of the

Ewing Galloway

Energy is being transformed in this welding process



Ewing Galloway

Both these balloons were the same size until one was held over the electric plate. Explain what has happened

water. We call this *diffusion.* The molecules of water begin to bombard the molecules of potassium permanganate in the crystal, and soon the crystal disintegrates as the molecules of the two substances intermingle. Can you suggest other experiments which would produce the same results?

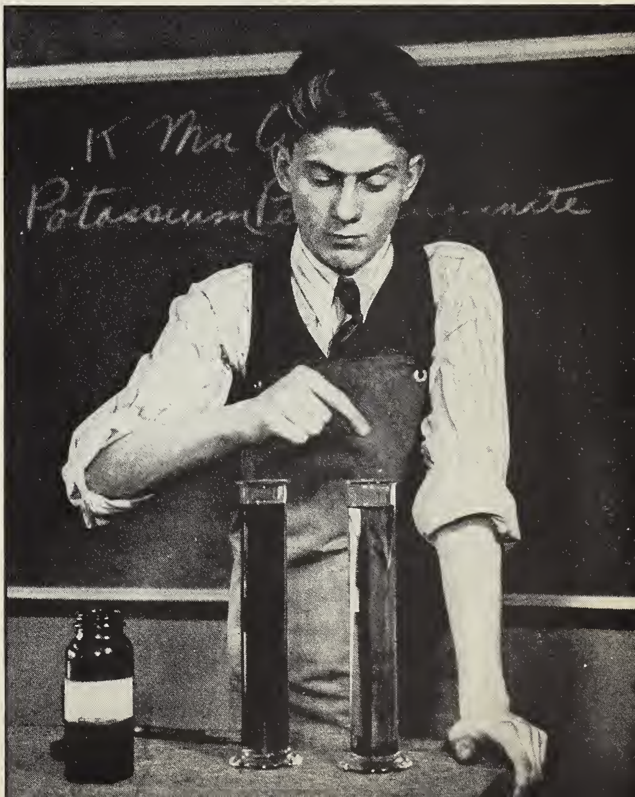
Even in solids there is a constant state of motion between the molecules. The motion is so slight that it cannot be perceived by casual observation. If a gold coin is placed on a silver coin under pressure and left for a considerable length of time, some of the gold molecules actually work down into the silver, and some of the silver molecules go up and intermingle with the gold molecules. Chemical analysis of the coins will prove this to be true.

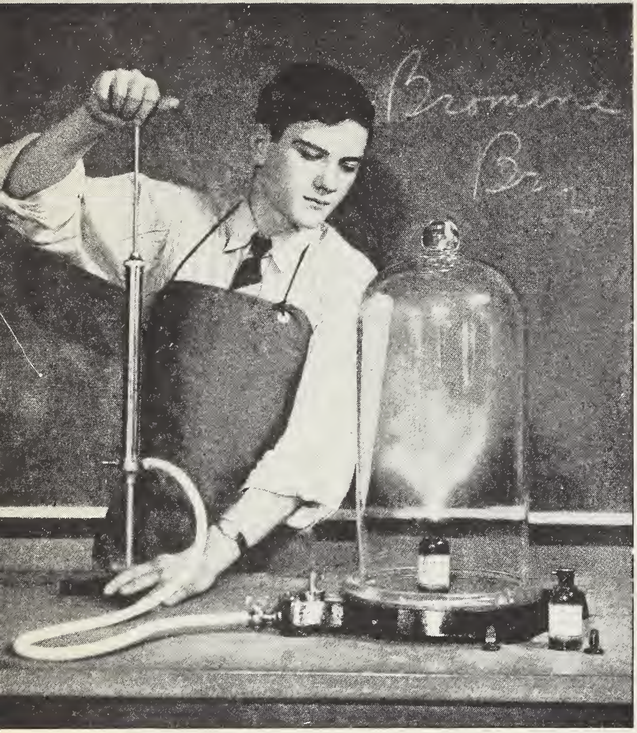
What is the kinetic theory of matter? The molecules of all substances are in a state of constant motion. Heat increases this motion. The different states of matter are due to the different speeds with which molecules move. In solids the molecules are relatively close together, not packed tightly, but still so close that their attraction for one another holds each molecule so that it can move only in a very restricted area and retains a fixed shape. In liquids the molecules are farther apart and are more mobile. The space in which these molecules move is greater, and therefore the form of the substance is less rigid than that of a solid. Consequently a liquid has no shape of its own but takes the form of the containing vessel. In a gas, such as air, the molecules are far apart and have great freedom of motion. The space in which these molecules move is without limit. Therefore a gas does not have a definite shape or size. We might compare a bottle of gas, with its millions of moving molecules, to a swarm of bees, each molecule being similar to a bee in the swarm.

We can change the physical state of a substance by simply increasing the speed of the molecules. Water begins to boil and change into a gas when the speed of the molecules reaches a certain point. The

The student is dropping crystals of potassium permanganate into the cylinder of clear water on the right. The cylinder on the left shows what has happened after a few hours have elapsed. Explain why the water has become colored

Ewing Galloway





Ewing Galloway

Explain why the bromine gas is coming from the mouth of the bottle which is in a partial vacuum but not from that of the bottle exposed to normal air pressure

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distance between the molecules is then increased greatly, as is shown by the fact that 1 gallon (abbreviated gal) of water will produce over 1200 gallons of steam.

The kinetic theory of matter states that the molecules of matter are in a state of constant motion.

EXERCISES

1. Is the boiling point of a liquid always higher than its freezing point? Give a reason for your answer.

2. What energy changes accompany the changing of a solid into a liquid? the changing of a liquid into a gas?

3. Is it correct to say that sugar melts when it is put into water? Why?

4. What causes a rubber balloon filled with hydrogen or helium to burst if it is allowed to go uncontrolled into the stratosphere?

5. What are two ways by means of which the molecules of a gas can be packed more closely together?

6. If you compress a gas, what heat change will occur?

7. What change occurs in an iron bar when it is heated or cooled which tends to prove that its molecules move?

8. What heat change occurs when a gas under pressure is allowed to expand?

9. What causes sidewalks to bulge during the intense heat of summer?

10. In what ways is man able to use the energy of moving molecules?

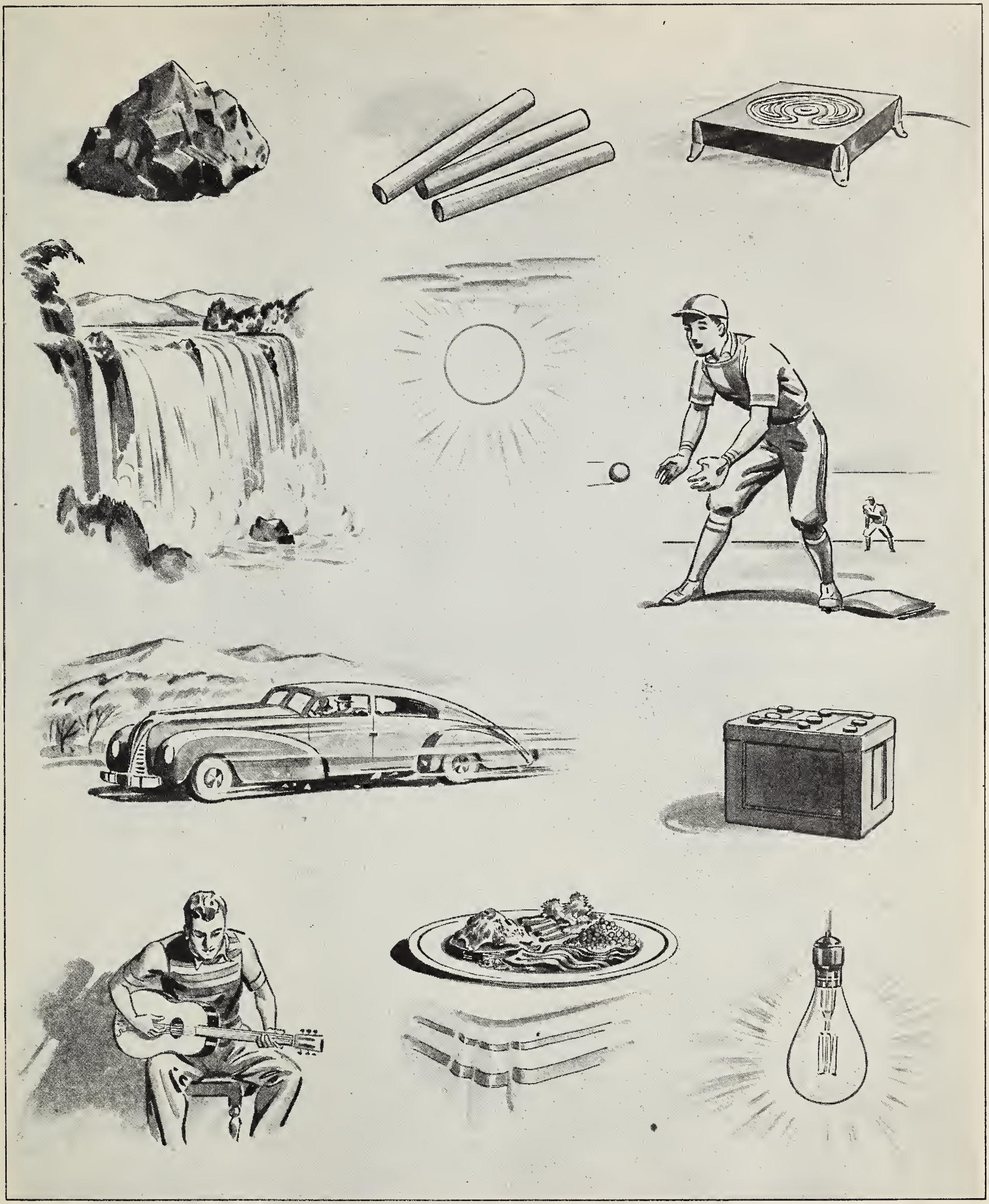
Problem 2. What is energy?

Energy and matter. We recognize energy through its effect upon matter. *Energy is commonly thought of as the ability, or the capacity, to do work.* When work is being done, we know that energy is being expended. Since it takes energy to put matter to work, that is, to put it into motion, energy and work are the same. Work may be considered a form of energy. Not all energy is in the form of matter in motion. A lump of coal in a bin certainly has the ability to heat water. Dynamite looks perfectly innocent; yet within it lies the force to blast tunnels through mountains of stone. Energy which lies dormant is called *potential energy.*

When coal is placed in a furnace and ignited, it is actually giving off heat and raising the temperature of the water. When a hunter fires a gun, the powder explodes and sends the shot toward the rabbit. The effect produced by a shot hitting a rabbit is due to kinetic energy. All matter in motion possesses *kinetic energy.*

Forms of energy. The classification of energy as potential and kinetic is based upon whether the energy is stored up or whether it is due to matter in motion. It is, however, convenient and useful to classify energy according to types, or forms. The most common classification according to type, or form, is (1) mechanical, (2) heat, (3) sound, (4) light, (5) electrical, and (6) chemical. Can you give examples of each?

In the study of chemistry we are vitally interested in chemical energy—the energy of a substance by virtue of which it undergoes chemical change. Food is an excellent example of a substance having chemical energy. When sugars, starch, fats, and proteins are burned in the body, their chemical energy is transformed into heat and mechanical energy, which are essential to body functions.



Name the different kinds of energy shown in these pictures

General Electric Company

Three eminent American scientists who have contributed much to our knowledge of atoms, molecules, and their movements. They are, from left to right, Dr. Willis R. Whitney, Dr. W. D. Coolidge, and Dr. Irving Langmuir. In this picture they are shown studying the effects of oil film on water

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EXERCISES

1. Give an example of the use of each kind of energy and explain how each is controlled.

2. Explain how a lump of coal contains energy. Would there be a similar amount of energy in a piece of sandstone of the same weight? Why?

3. Do you think that man has discovered all the materials from which he can obtain energy?

4. Which of the common kinds of fuels possess the most energy per pound?

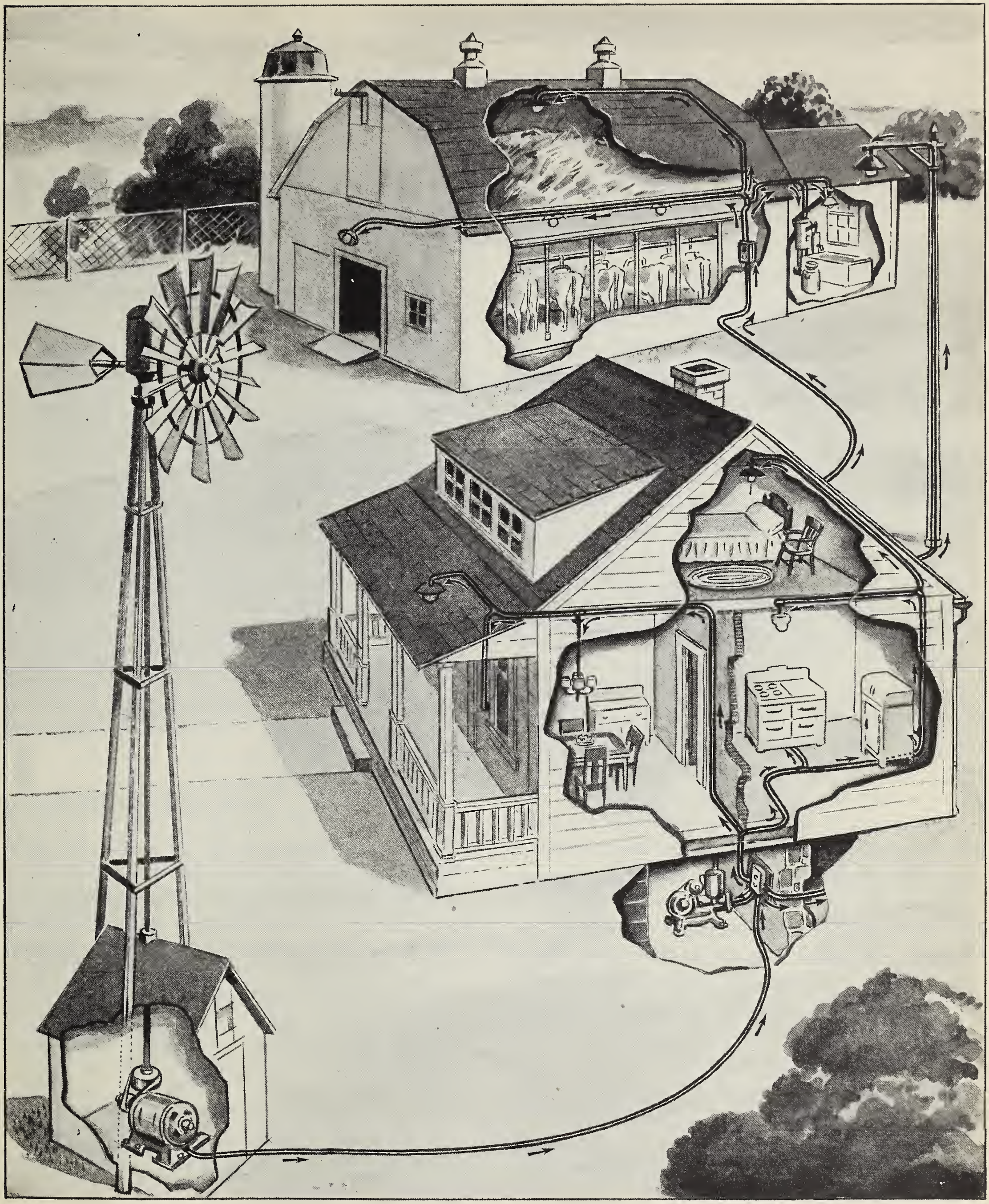
5. What food material furnishes you with the most energy per pound?

6. In what state is the energy in the storage battery of a car in a garage?

Problem 3. How may man transform and use energy?

The law of the conservation of energy. This law states that man can neither create nor destroy energy. He is able, however, to transform energy from one kind to another. This principle may be illustrated by the fact that when coal burns in a furnace, heat is given off, which may cause water in a boiler to change to steam. The steam may be used to turn a turbine which runs a dynamo which generates electricity. You may give further proof of the transformation of energy by showing how the energy of an electric-light bulb or of gasoline is traceable to the sun, from which all of our energy comes.

Man uses energy. Man's progress through the ages can be traced through his discoveries of methods of transforming energy into forms which will do work. Man is master over matter only through the utilization of energy. He has utilized such an energy transformation as that of the atoms of one



Energy transformations in the house and on the farm element uniting with the atoms of another element to form the molecules of a compound. Any compound represents stored-up, or potential, chemical energy. Some compounds have more usable energy than others. An example of the release and transformation of this potential energy may be found in dynamite or TNT. When either of the compounds is set off, or detonated, the stored-up energy may be transformed into useful mechanical energy sufficient to bore tunnels, to blast mammoth holes, or to mine valuable ores. Another common example of the utilization of chemical energy is that of burning gasoline in automobiles. Here the potential energy of the gasoline is transformed into the mechanical energy required to drive a car. Still another example may be found in the storage battery. When the substances in a storage battery react with one another, chemical energy is transformed into electrical energy. Much of the progress of our modern civilization depends upon our knowledge of how to use the stored-up energy of compounds.

As man has put the different forces of nature to work, there has been a corresponding change in his social and economic life. What discoveries accompanied the Renaissance? How could these discoveries bring about the important changes in the lives of the people that they did? Do you know what changes brought about the industrial revolution in Great Britain? Ask your social-science teacher to give you reference material on this subject.

As man puts the machine to work, either he must develop new fields of endeavor or he must work less. Sometimes it is hard to adjust the economic system to the new conditions created by the new developments of science, and men are thrown out of work. The result is economic depression. Social and economic progress have always lagged behind scientific and industrial progress. Why do you think this has been true?

EXERCISES

1. Give five examples of matter possessing potential energy; kinetic energy.

2. Give two examples of the use of each of the following kinds of energy: (*a*) light, (*b*) heat, (*c*) electrical, (*d*) mechanical, (*e*) sound, and (*f*) chemical.

3. How has your life been made more enjoyable by man's ability to make use of energy?

4. Trace the transformation of energy produced at Boulder Dam through the communities in which the energy is used.

5. Show how the law of the conservation of energy is of economic importance.

UNIT EXERCISES

A. On a separate piece of paper write *false* for each statement that is false and *true* for each statement that is true. Make a true statement of each one which is false. Do not write in this book.

1. All energy on the earth comes from the sun.

2. The energy stored in a lump of coal is called chemical energy.

3. The energy of light may be transformed into mechanical energy.

4. Sound is a form of energy which cannot be transformed into other kinds of energy.

5. The law of the conservation of energy states that energy may be stored up.

6. Energy is the capacity to do work.

7. Energy can be utilized only in the presence of matter.

8. Cellulose possesses energy which the human body can use to build tissue.

B. On a separate piece of paper write whatever is necessary to make each statement complete. Do not write in this book.

1, 2. The law of the conservation of energy states that energy may be neither --(?)-- nor --(?)--.

3. Edible food possesses --(?)-- energy.

4, 5. The --(?)-- energy of a waterfall may be converted into --(?)-- energy.

6, 7. Energy in the form of --(?)-- must be applied to a liquid to change it into a --(?)--.

8, 9. Energy in the form of --(?)-- must be withdrawn from a --(?)-- to change it into the solid state.

10. The pressure in an automobile tire is due to the --(?)-- of molecules.

11. When a gas is compressed, it gives off --(?)--.

12. Wind is an example of --(?)-- energy.

13, 14. The storage battery is an example of the transformation of --(?)-- energy into --(?)-- energy.

15. Dynamite possesses --(?)-- energy.

REFERENCES FOR FURTHER READING

Millikan, Gale, and Coyle. *New Elementary Physics.* Ginn and Company, Boston, 1941.

Williard, Lester R. *Experiences in Physics.* Ginn and Company, Boston, 1939.

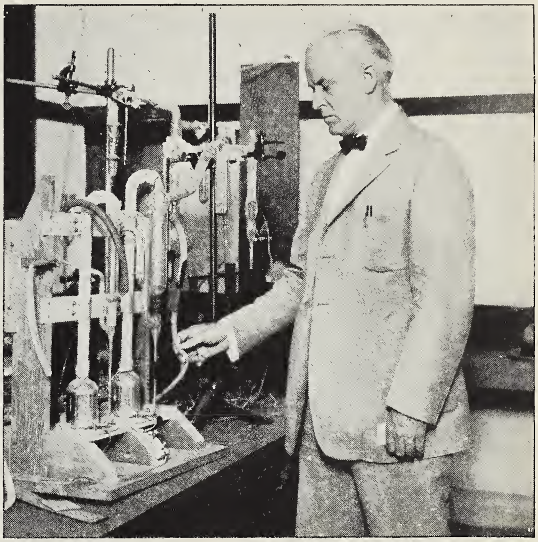
UNIT 4

The Structure of Matter

In a previous unit you learned that matter is made up of molecules and that these molecules are composed of atoms. You may now rightfully ask, "Can atoms be further divided into smaller particles?" Since scientists first began to study this problem, it has been a puzzling one. In recent years discoveries have been made which give us at least a partial answer. The X-ray tube and the disintegrating elements, such as radium, have been the tools that the scientists Madame Curie, Moseley, Millikan, and others have used to study the interior of matter. The results of the work of these geniuses of scientific research indicate that the building blocks out of which atoms are made are very minute electrically charged particles called electrons and protons. The electron is a negatively charged particle; the proton, a positively charged particle. Elements differ from one another in all properties solely because of the different numbers of these particles in their atoms. A study of these particles will help us to answer many questions about chemical changes that formerly could not be answered. For example, an understanding of these particles shows us why elements have combining power; why the combining powers of elements differ; why the metals are different from the nonmetals; and why some elements will not combine with others at all. Let us see from the following how these questions can be answered.

PURPOSES TO BE ACHIEVED

1. To obtain a mental picture of the inside of atoms.
2. To learn what determines the combining power of the elements.
3. To discover the reasons for such things as (*a*) the classification of elements into metals and nonmetals; (*b*) the differing degrees of chemical activity of elements.



Keystone

Robert Andrews Millikan (1868–   ) is one of America's most brilliant scientists. He won the Nobel prize for his work on the isolation and weighing of the electron. He is now director of the California Institute of Technology, at Pasadena

PROBLEMS TO BE SOLVED

1. What is the structure of the atom?
2. Why do elements unite with one another to form compounds?
3. What is the difference between metals and nonmetals?

Problem 1. What is the structure of the atom?

The combining power of elements. It has been known for a long time that the molecules of chemical compounds are made up of a definite number of different elements. We now know that every molecule of water is made up of two atoms of hydrogen united with one atom of oxygen. However, every molecule of the compound hydrogen chloride is made up of one atom of hydrogen united with one atom of chlorine. In attempting to explain

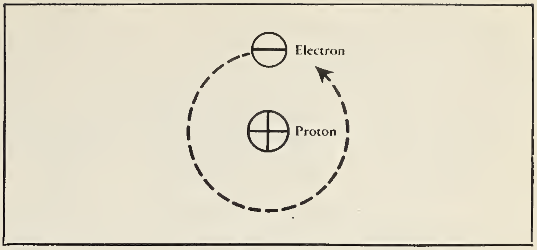
The structure of the atom suggests the structure of the universe why oxygen can combine with two atoms of hydrogen, while chlorine can combine with only one atom of hydrogen, early chemists said that oxygen had a greater combining power than chlorine. Since one atom of sodium will combine with only one atom of chlorine, it is said that sodium has the same power of combining with other elements as hydrogen, or a power of 1. This combining power which elements have, or power of uniting with one another, is called *valence.*

The meaning of valence was not clearly understood until it was discovered that atoms are made up of electrically charged particles. An understanding of the electrical structure of atoms helps to explain such things as the cause and speed of chemical action, the properties of elements, and how and why elements are classified.

The interior of the atom. What are the particles inside the atom? The exact nature of the interior of an atom is not fully understood, but sufficient evidence has been obtained to identify at least three electrical particles which make up atoms. These are called electrons, protons, and neutrons. An electron is a tiny particle of matter bearing a negative (—) charge of electricity. It is extremely light in weight, having only $\frac{1}{1845}$ the weight of a hydrogen atom. A proton is a particle of matter bearing a positive charge (+) of electricity. It is much heavier than an electron, having $\frac{1844}{1845}$ the weight of a hydrogen atom. A neutron is a neutral particle having no electrical charge. It is made up of one electron and one proton in close association. Some investigators designate even a fourth particle, called a positron, which is described as a particle having the same weight as an electron but bearing a positive (+) charge.

We now recognize that electrons, protons, and neutrons are the real building blocks of matter. Furthermore, electrons are exactly the same, whether found in oxygen atoms or gold atoms. The same thing may be said of protons and neutrons.

In every atom of an element in the free, or uncombined, state there is always the same number of electrons as of protons. As each proton has a positive charge and each electron has a negative charge, equal numbers of the two, as found in any atom, will neutralize each other, and the atom will be neutral, or without electrical charge.



Structure of hydrogen atom

The central part of the atom, called the nucleus, contains more protons than electrons. Since the atom is neutral, there must be other electrons, equal to this excess, located outside the nucleus. The additional electrons are constantly moving in paths, or orbits, around the nucleus. The properties of an element are determined by the structure, or distribution of parts, of its atoms. The atoms of elements differ from each other in all properties because no two of them have the same number of electrons, protons, and neutrons.

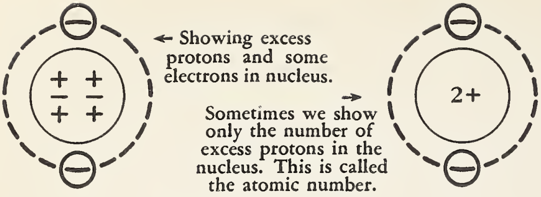
Hydrogen, the lightest of all the elements, has only one proton in the nucleus. It has one electron to neutralize this proton, circling about the nucleus in an orbit. Hydrogen is the only element which does not have an electron in its nucleus.

The atom of helium is next above hydrogen in atomic weight and has an excess of two protons in the nucleus. There must be two electrons in an orbit about the nucleus, neutralizing these two protons. Since there is an equal number of positive and negative charges within the atom, the net charge is zero.

You must realize the limitations to such diagrams as those shown on these pages, for they picture the atom in only two dimensions. It is safe for us to assume that since atoms are material things and occupy space, they are not in the form of disks but have three dimensions and are probably spherical.

The nucleus of the hydrogen atom contains one proton, and that of the helium atom an excess of two. These numbers are called *atomic numbers.* The atomic number of any element is equal to the excess of protons in the nucleus of its atom.

As the atomic weight of an element increases, the number of protons, electrons, and neutrons that make up the atom increases. Study the diagrams of a few of the elements given on the next page.



← Showing excess protons and some electrons in nucleus.

→ Sometimes we show only the number of excess protons in the nucleus. This is called the atomic number.

Structure of helium atom

You will notice that lithium has an atomic number of 3. Two of the electrons revolve in an orbit close to the nucleus, while the third revolves farther out in another orbit. There are never more than two electrons in the first orbit.

Study each element in the chart, and you will notice that in the outside orbit there are never more than eight electrons. Neon has an atomic number of 10, and therefore has two electrons in the first, or *K*, orbit and the remaining eight in the second, or *L*, orbit. Sodium, with an atomic number of 11, has two electrons in the *K* orbit and eight in the *L* orbit. Since the outside orbit can never have more than eight electrons, the other electron of sodium revolves in another orbit by itself, still farther from the nucleus.

The diagrams on page 43 show several heavy atoms. The interior orbits sometimes have more than eight electrons, but the outside orbit never has more than eight.

There are 92 elements, and the atomic numbers range from 1 to 92, the atomic number of any element being the same as the number of excess protons in the nucleus. This is equivalent to the number of electrons in the orbits outside the nucleus. You will be able to find the atomic numbers of the elements in the table on the inside of the back cover of this book.

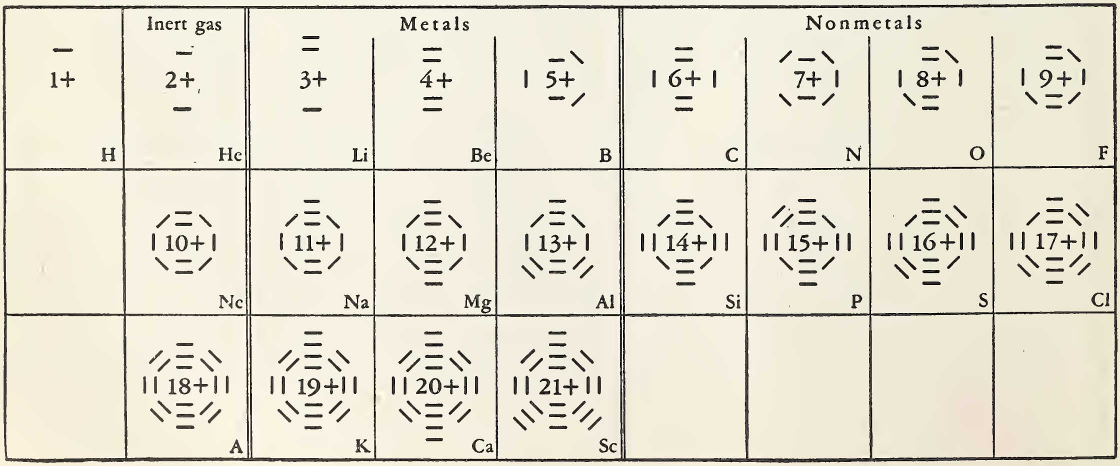
EXERCISES

1. Define the term *valence* as it was explained above.
2. Why is the atom said to be neutral?
3. What is the number of electrons in the orbits of an atom of (*a*) sodium; (*b*) oxygen; (*c*) chlorine?
4. How many protons does each atom of the elements mentioned in Exercise 3 contain?
5. What determines the atomic weight of an element?
6. What determines the atomic number of an element?

Problem 2. Why do elements unite with one another to form compounds?

Atoms have a tendency to complete their outside orbit. Several of the elements, such as argon and neon, have completed outside orbits of eight electrons. These elements do not unite with other elements, because they do not need to gain or lose electrons to reach a stable state. Elements such as argon and neon are said to be inert. Since not all atoms have eight electrons in the outside orbit, there are two ways by which they may attain a completed outside orbit. First, they may gain enough electrons from some other source to com-

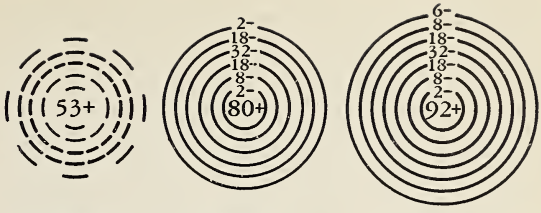
Showing the arrangement of electrons about the nucleus. The excess number of protons (the atomic number) in the nucleus of some elements is given



plete the outside orbit, or, second, they may lose the electrons in the outside orbit, thus leaving the next orbit complete. For example, chlorine has seven electrons in the outside orbit of its atom. Chlorine, then, may either lose all seven electrons and have a complete outside orbit, or it may secure another electron from another source to complete its orbit. Obviously, it would be easier for it to gain one electron from another source than to lose all seven. Sodium, on the other hand, has only one electron in its outside orbit. It would appear that it might be much easier for it to lose this one electron than to gain seven others in securing a completed outside orbit. What do you think an atom of carbon or silicon would tend to do? Why?

How do atoms lose or secure electrons in order to have a completed outside orbit? As long as the element sodium is in the free, uncombined state it retains the lone electron in the outside orbit. It cannot just cast off this electron into the air. However, if we place some sodium in a bottle containing the element chlorine, we notice a chemical change taking place. This is proved by the presence of a new substance, sodium chloride, or table salt, which is formed. It has entirely new chemical and physical properties. Let us see what happens to the atoms and their electrons when the elements sodium and chlorine unite chemically to form the compound sodium chloride. The sodium atom, with one electron in its outside orbit, loses this electron to the chlorine atom. This loss leaves the sodium atom with a completed outside orbit of eight electrons. Chlorine, in turn, with seven electrons, needs only one electron to fill its orbit.

When the element aluminum burns in the flash bulb used by photographers in taking pictures, a great deal of light is given off instantly. This light is the energy produced as the countless number of atoms of aluminum present in the foil lose electrons to the oxygen gas which is in the bulb. Look at the chart again. How many electrons will an atom of aluminum tend to lose? How many electrons does oxygen tend to gain in order to complete its outside orbit? Since oxygen needs only two electrons and aluminum has three to lose, they will have to get together in a ratio corresponding to these numbers. In other words, two aluminum atoms will lose six electrons, which are taken by three oxygen atoms. Therefore the formula for the white compound that is the product of the reaction must be Al_2O_3. (See diagram on page 44.)



Iodine
Atomic wt. 127

Mercury
Atomic wt. 200

Uranium
Atomic wt. 238

Theoretic arrangement of electrons about the nucleus of three heavy atoms: iodine, mercury, and uranium

Why do elements have different valences? Since sodium loses only one electron, it has a combining power of 1. Chlorine, on the other hand, will have a valence of 1 when it receives one electron. Therefore, when sodium combines with chlorine, the formula must be NaCl, since there is an equal transfer of electrons. Calcium has a combining power, or valence, of 2, since it loses two electrons. When calcium unites with chlorine, the formula must be $CaCl_2$, since it will require two chlorine atoms to receive the two electrons that the calcium loses. Likewise, the formula of aluminum chloride is $AlCl_3$.

Why do some atoms have a negative and some a positive valence? If you will look again at the diagram of the sodium atom on page 42, you will notice that there are eleven excess protons in the nucleus, surrounded by eleven electrons in orbits; these protons and electrons exactly neutralize each other, and the charge on the atom is zero (Na^0). Chlorine has seventeen excess protons in the nucleus and seventeen electrons in the orbits in each atom, and when uncombined has a charge of zero (Cl^0).

When sodium loses its electron to chlorine in forming NaCl, it takes on new properties and now has eleven excess protons in the nucleus and only ten negative electrons. When the Na atom gives away the negative electron, it takes a positive charge of 1, and it is now called a sodium *ion.* The chlorine atom, in taking on the electron from the sodium atom, will become a negatively charged chloride ion because of the excess of one electron over its protons. Though atoms of elements may exist by themselves, ions are always parts of compounds.

When atoms lose electrons, they take on positive charges; and when they acquire electrons, they take on negative charges. The valence of any element, then, depends upon the number of electrons it loses or gains. If it loses one electron, it is said to have a valence of 1+; and if it receives one electron, it is said to have a valence of 1−. Aluminum has a valence of 3+ because it loses three electrons, and oxygen has a valence of 2− because it gains two electrons.

EXERCISES

1. Explain what happens to the electrons in the outer orbit of an atom of sodium and of an atom of chlorine when these two elements combine to form sodium chloride.

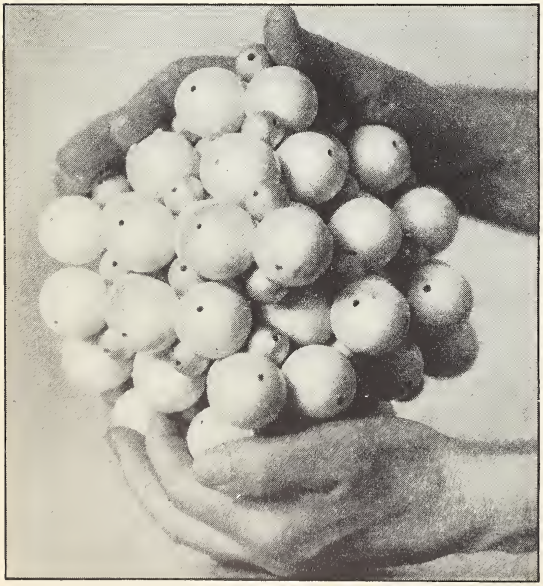
2. When an atom of an element loses or gains electrons, where do the electrons go?

3. Name ten elements which have positive valences. What name is applied to such elements?

4. Name five elements which generally gain electrons to fill the outer orbit.

A model of the arrangement of atoms in sapphire, which is a crystalline form of corundum, or aluminum oxide (Al_2O_3). The atomic spacing is disclosed by the use of the X ray. This model is built to scale, with 1 inch representing 2 angstroms. An angstrom is 0.000,000,003,937 inch

General Electric Company



5. What is the difference between an ion and an atom?

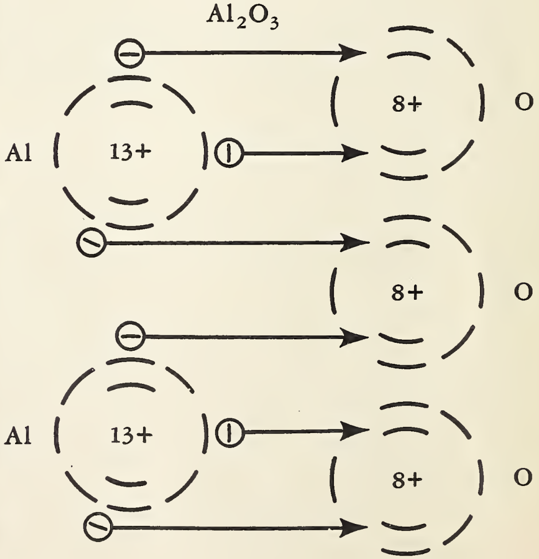
6. What determines the amount of valence which an atom possesses?

Problem 3. What is the difference between metals and nonmetals?

Metals have a positive valence. Metals always lose electrons when they unite with other elements and therefore must have a positive valence. Some metallic elements may have more than one valence, owing to the fact that in a chemical reaction their atoms lose more than the normal number of electrons. Thus atoms of iron, under certain conditions, may lose three electrons and have a valence of 3+, while under other conditions the atoms may lose only two electrons and have a valence of 2+.

Since all metals lose electrons, they do not react with one another. When copper and zinc are melted together, they form a substance called brass. If we study the composition of this substance, it will be found that the little atoms of each element have not united with one another. They are simply mixed together. When two or more metals are melted together in this way, the substance formed is called an *alloy.*

A graphic representation of the reaction between aluminum and oxygen to form aluminum oxide



Nonmetals have a negative valence. Nonmetals may either gain or lose electrons, though they usually gain rather than lose. Like metals, some nonmetallic elements may gain less than the normal number of electrons and consequently have more than one valence. Thus, when carbon unites with oxygen to form CO_2, it loses four electrons and has a valence of 4+; but when it unites with hydrogen to form H_4C (methane, usually written CH_4), it gains the four electrons from the four hydrogen atoms and has a valence of 4−. Carbon is an example of an element which has its outside orbit half full. Such elements often exhibit both metallic and nonmetallic properties.[1]

EXERCISES

1. Why do we say that nonmetals usually possess negative valence?

2. Why do the inert elements, such as helium and neon, have no valence?

3. If a nonmetallic element loses electrons to another nonmetallic element, what kind of valence does the first element exhibit?

UNIT EXERCISES

A. On a piece of paper, write the missing words for the following statements. Do not write in this book.

1. The smallest particle of hydrogen chloride which can exist is the --(?)--.

2. The combining power of an element is called its --(?)--.

3. The discovery of the --(?)-- aided in determining the structure of matter.

4. Positively charged particles in atoms are called --(?)--.

5. Negatively charged particles in atoms are called --(?)--.

6. The central portion of an atom is called its --(?)--.

7. When an atom gains or loses electrons so that there is an unequal number of electrons and protons, it is then called an --(?).

8. A --(?)-- change takes place when electrons are lost by one element to another.

9. The element --(?)-- contains the smallest number of electrons and protons.

10. Elements which always lose electrons are classed as --(?)--.

11. When two or more metals are melted together, as in bronze, the mixture is called an --(?)--.

12. When Al unites with O to form Al_2O_3, its valence is 3+ because it --(?)-- three electrons.

13. Oxygen is a nonmetal because it always --(?)-- electrons.

14. Oxygen has --(?)-- electrons in its outer orbit.

15. The iron atom may have a valence of 2 or 3, depending on whether it --(?)-- 2 or 3 electrons.

16. An element whose outside orbit contains eight electrons is said to be --(?)--.

17. An example of such an element is --(?)--.

18. When an element has four electrons in its outside orbit, it may act either as a --(?)-- or as a --(?)--.

B. **1.** Diagram the structure of each of the following atoms: (*a*) calcium, (*b*) fluorine, (*c*) potassium, (*d*) sulfur, (*e*) aluminum, (*f*) hydrogen, (*g*) oxygen, and (*h*) carbon.

2. Show by diagrams how the following compounds are formed by electronic transfer: (*a*) calcium fluoride, (*b*) potassium sulfide, (*c*) aluminum chloride, (*d*) water, and (*e*) carbon dioxide.

REFERENCES FOR FURTHER READING

Foster, William. *The Romance of Chemistry.* D. Appleton-Century Company, Inc., New York, 1936.

Harrow, Benjamin. *The Romance of the Atom.* Boni & Liveright, New York, 1927.

Langdon-Davies, John. *Inside the Atom.* Harper & Brothers, New York, 1933.

Thomson, J. Arthur. *The Outline of Science.* G. P. Putnam's Sons, New York, 1922.

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[1] You will find a discussion of the periodic law in the Appendix. Your teacher may wish you to study this law and the periodic table at this time.

UNIT 5

Chemical Formulas

One of the mysterious and intriguing things about chemistry to the freshman or sophomore, as he passes the chemistry laboratory door and sniffs the unusual odors, is the curious and unintelligible signs on the blackboard. He is puzzled by the formulas and equations he sees, and may think that these are used just to make chemistry more complicated than it naturally is. In reality, this is not true. A chemist uses formulas and equations to make the facts he wishes to convey more intelligible. A glance at a formula tells the chemist not only what elements are present in a compound, but also just how many atoms of each element are present in one molecule of the compound.

You will need to know how to write the formulas of some of the common substances found in the home. The material in this unit will enable you to become proficient in formula-writing. You will then be able to read more intelligently the reference material needed to understand the applications of chemistry to everyday life. You will also acquire a much clearer understanding of why chemistry is an exact science.

PURPOSES TO BE ACHIEVED

1. To become skilled in using the chemist's shorthand by learning (*a*) the valences of elements and radicals; (*b*) how to write the formulas of chemical compounds.
2. To learn how to name chemical compounds.
3. To learn how the chemist computes the weight of a molecule.

PROBLEMS TO BE SOLVED

1. How does the chemist write chemical formulas?
2. How are chemical compounds named?
3. How is the weight of a molecule computed?
4. (Optional.) How can the percentage composition of a compound be determined from its formula?

Problem 1. How does the chemist write chemical formulas?

The technique of formula-writing. In your study of chemistry you will continually use the formulas of compounds. A formula is a short method of representing one molecule of a compound or an element. Moreover, it shows the elements which compose the molecule and how many atoms of each element are combined in forming the molecule.

If we know the valence of each element, it is easy to write the formula of the compound, because we know that the total number of electrons lost by the positive ions must equal the total number of electrons gained by the negative ions. A simple way of writing formulas is to write first the symbols of the elements which unite. For example, if we wanted to write the formula of aluminum oxide, we would begin by writing

$$\mathrm{Al\ O}$$

Next we would write the valence of each element above its symbol:

$$\overset{3+}{\mathrm{Al}}\ \ \overset{2-}{\mathrm{O}}$$

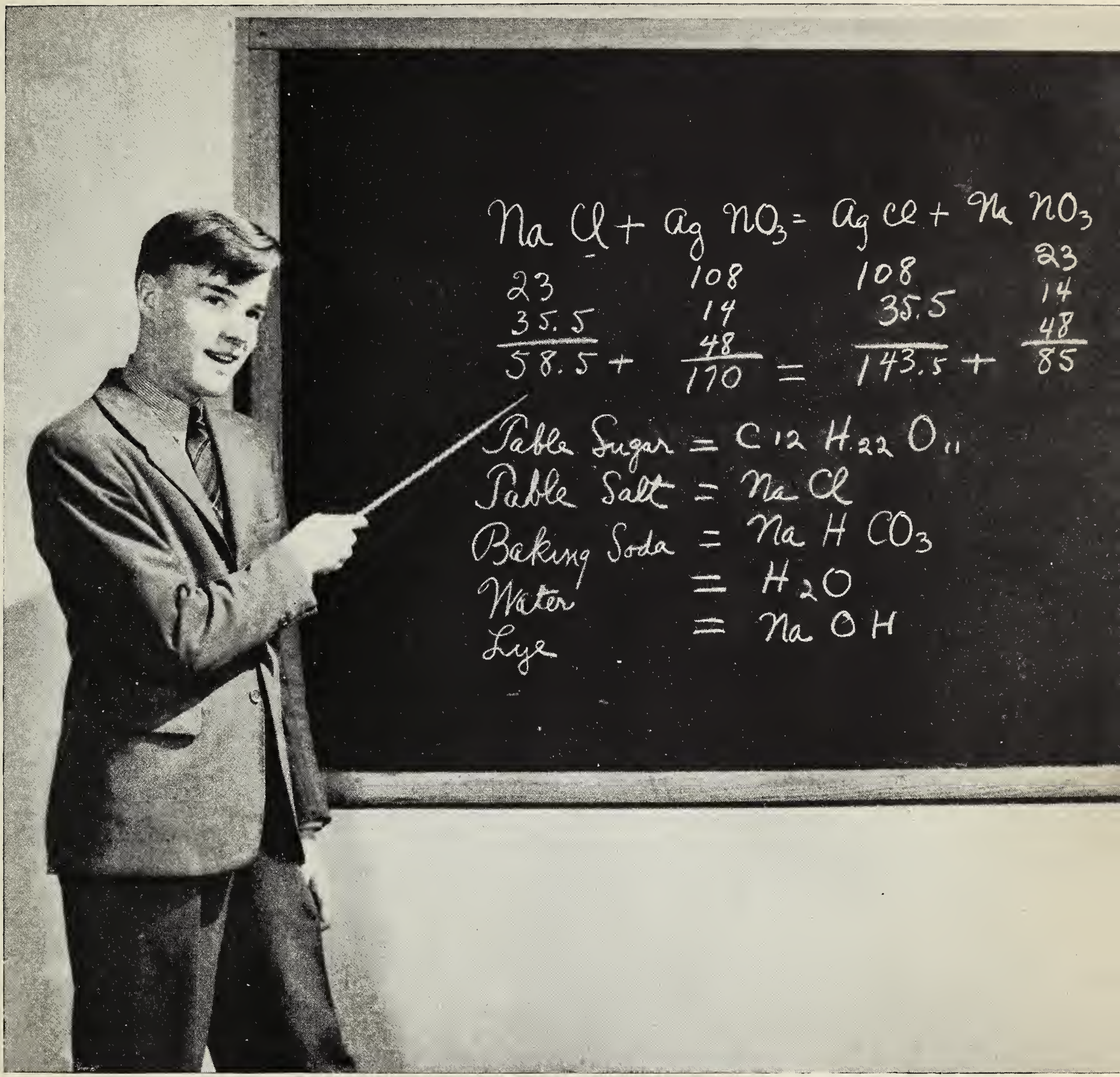
Then we would find the least common multiple (L.C.M.) of the valences, which in this case is *6*. We might place this L.C.M. above the provisional formula, thus:

$$\overset{6}{\overset{3+}{\mathrm{Al}}\ \ \overset{2-}{\mathrm{O}}}$$

When we divide the 3+ valence of aluminum into the L.C.M. *6*, we obtain the number 2, which is placed as a subscript of Al in the formula. Similarly the 2− valence of oxygen divided into the L.C.M. *6* will yield the subscript 3 for oxygen, making the formula for aluminum oxide

$$\mathrm{Al_2O_3}$$

The knowledge of the electronic structure of atoms gives us a scientific explanation of why the formula of aluminum oxide is $\mathrm{Al_2O_3}$. Aluminum



Ewing Galloway

Now that I know how to write chemical formulas,
chemistry is easier for me and more fascinating

has a valence of 3+ because each atom of Al loses three electrons. There are two atoms of Al in the molecule of Al_2O_3, so that a total of six electrons must be lost to the oxygen. Each molecule of oxygen has a valence of 2−; therefore each atom can gain only two electrons. Since there are three atoms of oxygen in the molecule, there is a total of six electrons gained.

Let us try another example by writing the formula for aluminum chloride, using the steps followed above:

Step 1	**Step 2**	**Step 3**	**Step 4**
Al Cl	$\overset{3+}{\mathrm{Al}}\ \overset{1-}{\mathrm{Cl}}$	$\overset{3}{\overset{3+}{\mathrm{Al}}\ \overset{1-}{\mathrm{Cl}}}$	Al_1Cl_3

We find that there is only one atom of Al in the compound and three of Cl. When only one atom is present, we do not place the number 1 by the symbol, but write the formula $AlCl_3$. You will notice that the positive ion is written first.

Another method of writing formulas which is commonly used may be illustrated in writing the formula of zinc sulfide. The first step is that of writing the symbols for zinc and sulfur:

$$\mathrm{Zn}\quad\mathrm{S}$$

Next give to zinc a subscript equal to the valence of sulfur and to sulfur a subscript equal to the valence of zinc:

$$Zn_2S_2$$

Then reduce the subscripts to their simplest terms (in this case divide by 2) and write the completed formula:

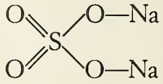
$$ZnS$$

Whichever method you choose to use, the process may, at the beginning, seem involved and tedious. However, as you proceed in the writing of formulas, you will soon learn to short-cut the process by remembering simply that every compound has the same total positive valence as it has total negative valence.

What is a radical? Sometimes two or more elements form a group which, in most chemical reactions, holds together as a unit. In solution these groups are ions and have either positive or negative charges. Since they are ions, they are parts of compounds and do not exist alone. Such ions are called *radicals*.

Each element in a radical has a valence, but the valence of the ion is the difference between the positive and the negative charges on the individual atoms. A common radical is the sulfate ion. It is written SO_4 and has a valence of 2−. It cannot exist alone, but must be combined with some positive ion; so it must always be part of a compound. We may have zinc sulfate ($ZnSO_4$) or aluminum sulfate ($Al_2(SO_4)_3$), but never just SO_4.

The following will describe the method of finding the valence of the SO_4 radical: The valence of sulfur in this radical is 6+, and that of oxygen is 2−. This means that the sulfur in the SO_4 radical has lost six electrons. Each oxygen atom, having a valence of 2−, gains two of these electrons. Since there are four atoms of oxygen, they must gain a total of eight electrons. The sulfur loses six electrons to the oxygen, leaving the oxygen two electrons short. The radical then must gain two more electrons and thus has a valence of 2−. For that reason, the formula for zinc sulfate must be $ZnSO_4$ because zinc will lose two electrons and has a valence of 2+.



This figure shows the structural formula for Na_2SO_4. It shows why the SO_4 radical has a valence of 2−.

What are the steps in writing formulas which contain radicals? The same rules apply to writing formulas containing radicals as to those containing only two elements. Let us write the formula for calcium phosphate. First, write each ion correctly with the positive ion first:

$$\mathrm{Ca}\quad PO_4$$

Second, place the valence above each ion:

$$\overset{2+}{\mathrm{Ca}}\quad \overset{3-}{PO_4}$$

Third, find the L.C.M. of the valences and place it in the center above the formula:

$$\overset{6}{\overset{2+}{\mathrm{Ca}}\quad \overset{3-}{PO_4}}$$

Fourth, divide the L.C.M. by the valence of each ion and place the number thus obtained as a subscript to show how many of that ion are needed. Thus 6 divided by 2 equals 3; therefore Ca has the subscript 3 (Ca_3), and 6 divided by 3 equals 2, causing PO_4 to have a subscript 2 ($(PO_4)_2$). If a radical is taken more than once it must be enclosed in parentheses:

$$Ca_3(PO_4)_2$$

After a little practice you will not need to place the valence or L.C.M. above the formulas, but will write the formula simply $Ca_3(PO_4)_2$.

When the formula for a chemical compound is correctly written, the total positive valence equals the total negative valence.

Actually the formulas of compounds must be determined by experimentation in the laboratory. Just because we can write the formula for a substance, we cannot be sure that such a compound actually exists or can be made. The formulas of most inorganic compounds (those which do not contain carbon) can be written, however, by the method you have learned.

The tables below show the common elements and radicals with their valences. Study these lists until you know all the symbols and the valences; memorize the lists. You should become so familiar with the valences of these common ions that you can write any of the formulas of their compounds automatically.

Valences of Common Positive Ions

Valence of 1		**Valence of 2**		**Valence of 3**	
Ammonium	NH_4	Lead	Pb	Chromium	Cr
Cuprous	Cu	Magnesium	Mg	Ferric	Fe
Hydrogen	H	Manganous	Mn	Phosphorous	P
Mercurous	Hg	Mercuric	Hg	**Valence of 4**	
Potassium	K	Nickel	Ni	Carbon	C
Silver	Ag	Stannous	Sn	Manganic	Mn
Sodium	Na	Strontium	Sr	Plumbic	Pb
Valence of 2		Zinc	Zn	Stannic	Sn
Barium	Ba	**Valence of 3**		Sulfur	S
Cadmium	Cd	Aluminum	Al	**Valence of 5**	
Calcium	Ca	Antimonous	Sb	Antimonic	Sb
Cobalt	Co	Arsenious	As	Arsenic	As
Copper	Cu	Bismuth	Bi	Phosphoric	P
Ferrous	Fe				

Valences of Common Negative Ions

Valence of 1		**Valence of 2**		**Valence of 3**	
Acetate	$C_2H_3O_2$	Carbonate	CO_3	Citrate	$C_6H_5O_7$
Bicarbonate	HCO_3	Chromate	CrO_4	Phosphate	PO_4
Bromide	Br	Dichromate	Cr_2O_7		
Chlorate	ClO_3	Oxalate	C_2O_4		
Chloride	Cl	Oxide	O		
Cyanide	CN	Silicate	SiO_3		
Fluoride	F	Sulfate	SO_4		
Hydroxide	OH	Sulfide	S		
Iodide	I	Sulfite	SO_3		
Nitrate	NO_3	Tartrate	$C_4H_4O_6$		
Nitrite	NO_2				
Permanganate	MnO_4				

EXERCISES

Write the formula for each of the following compounds:

Ferrous iodide
Cuprous sulfite
Copper sulfate
Manganese dioxide
Ammonium hydroxide ✓
Calcium hydroxide
Mercuric bromide
Lead chromate
Aluminum oxide
Zinc phosphate
Stannous chloride
Potassium chlorate
Nickel nitrate
Chromium carbonate
Ferric silicate
Silver cyanide
Hydrogen chloride
Mercurous fluoride
Arsenic oxalate
Stannic sulfate
Ferrous bicarbonate
Potassium permanganate
Ammonium phosphate
Aluminum sulfite
Cadmium chromate

Check your formulas. Did you fail to enclose the OH and other radicals in parentheses when they were taken more than once? When the positive ion and the negative ion each have the same valence, they unite evenly and are not taken more than once. When an ion is composed of a single element, it is never enclosed in parentheses, even when taken more than once.

Problem 2. How are chemical compounds named?

Naming compounds. The formula of a compound determines the suffix of its name. When one element unites with another to form a compound consisting of only two elements, the ending of the name of the compound is usually *ide*. Thus when calcium, with a valence of 2+, unites with oxygen, which has a valence of 2−, the formula for the compound is CaO, and it is called calcium oxide.

You will notice that several of the metals have two or more valences. When a metal of any compound is one having two common valences, the name of the ion with the smaller valence is given the ending *ous*, and the name of that with the larger valence is given the ending *ic*. Sometimes one of the valences is so much more common than the other that it does not usually take an ending but is called by the name of the metal. This is also true when the ion has only one valence.

For example, copper has two valences, 2+ and 1+, but the common valence is 2+. Such compounds are usually named simply copper salts and not cupric salts. We know that the formula for copper chloride is $CuCl_2$, while that of cuprous chloride is $CuCl$. $Pb(NO_3)_2$ is called lead nitrate instead of plumbous nitrate because the most common valence of that metal is 2+. Iron compounds containing both ferrous and ferric ions are rather common, so that we must give the proper ending to each. The tables of common valences give the name commonly applied to each ion.

As you studied the valence tables, you noticed that many of the names of oxygen-containing radicals had similar endings, the most common being *ate*. Examples are the sulfate ion (SO_4) and the nitrate ion (NO_3). When a radical has one less oxygen atom than such radicals as SO_4 and NO_3 (*ate* radicals), it is given the ending *ite*. Thus SO_3 is the sulfite ion, and NO_2 is the nitrite ion.

The name of a formula may require a prefix. The prefix *bi* in the name of the radical indicates that hydrogen is a part of the negative radical. $NaHCO_3$ is sodium bicarbonate, while Na_2CO_3 is sodium carbonate. In addition to the prefix *bi*, chemists also use the words *acid* and *hydrogen* before the names of formulas. For example, $NaHSO_4$ can be called sodium bisulfate, sodium acid sulfate, or sodium hydrogen sulfate.

The prefix *di* indicates that the element is taken twice and *mono* that it is taken only once. The prefixes *tri*, *tetra* or *tetr*, and *penta* or *pent* indicate that the element is taken three, four, and five times respectively. Examples are CO, carbon monoxide; CO_2, carbon dioxide; and SO_3, sulfur trioxide (not to be confused with the sulfite radical). CCl_4 is carbon tetrachloride, and P_2O_5 is phosphorus pentoxide.

EXERCISES

Write the name of the compound for each of the following formulas:

$KHCO_3$
$CaCO_3$
$Ni(NO_3)_2$
$Fe_2(SO_4)_3$
$AlCl_3$
$Bi(C_2H_3O_2)_3$
$NaNO_2$
Ag_2S
$CdSO_3$
$(NH_4)_2CrO_4$
$Ca(HCO_3)_2$
$FeCl_2$
$FeCl_3$
CuO
Cu_2O
HgI
HgI_2
SnS
SnS_2
SO_2

Problem 3. How is the weight of a molecule computed?

The molecular weight of a compound. Sometimes the chemist needs to know the weight of the molecule of a compound. We have learned that we can write the formula for a chemical compound because its molecule has a definite composition. Since every element has a definite atomic weight, *the weight of the molecule is equal to the sum of the weights of the atoms that compose it.* The molecular weight of potassium nitrate (KNO_3), then, is computed by adding the weights of one K atom, which is 39, one N atom, which is 14, and three oxygen atoms, which is 3 × 16, or 48, making a total of 101. This figure is the approximate molecular weight of KNO_3. The molecular weight of $Al_2(SO_4)_3$ can be similarly calculated as follows:

$$\begin{aligned} 2\ \mathrm{Al} &= 2 \times 27 = 54 \\ 3\ \mathrm{S} &= 3 \times 32 = 96 \\ 12\ \mathrm{O} &= 12 \times 16 = \underline{192} \\ \text{Molecular weight of } Al_2(SO_4)_3 &= 342 \end{aligned}$$

The molecular weight of a compound expressed in grams is called the *gram-molecular weight* of the compound.

EXERCISES

Using the table of atomic weights in the back of the book, determine the molecular weight of (1) sodium sulfate; (2) aluminum acetate; (3) ferric carbonate; (4) cobalt chloride; (5) silver nitrate; (6) barium oxide; (7) ammonium phosphate; (8) sulfuric acid; (9) calcium hydroxide; (10) magnesium iodide.

Problem 4. (Optional.) How can the percentage composition of a compound be determined from its formula?

After you have learned how to compute the molecular weight of a compound, the percentage of each element in the compound can be easily determined. The following examples will illustrate the method you may use:

Example A. What is the percentage of carbon and oxygen in carbon monoxide?

Step 1. Find the molecular weight of CO.

Atomic weight of one atom of C = 12
Atomic weight of one atom of O = $\underline{16}$
Molecular weight of CO = 28

Step 2. To find the percentage composition, divide the atomic weight of each element by the molecular weight of the compound and multiply by 100.

Percentage of C = $\frac{12}{28} \times 100 = 42.9$ per cent
Percentage of O = $\frac{16}{28} \times 100 = 57.1$ per cent

The sum of the percentages should total approximately 100. Thus 100 ounces (abbreviated oz) of CO contains approximately 42.9 ounces of carbon and 57.1 ounces of oxygen.

Example B. Find the percentage composition of $Al_2(SO_4)_3$.

Step 1. Find the molecular weight of $Al_2(SO_4)_3$.

Atomic weight of two atoms of Al = 54
Atomic weight of three atoms of S = 96
Atomic weight of twelve atoms of O = $\underline{192}$
Molecular weight of whole molecule = 342

Step 2. To find the percentage composition, divide the total of the atomic weights of each element by the molecular weight of $Al_2(SO_4)_3$ and multiply by 100.

Percentage of Al = $\frac{54}{342} \times 100 = 15.8$ per cent
Percentage of S = $\frac{96}{342} \times 100 = 28.1$ per cent
Percentage of O = $\frac{192}{342} \times 100 = \underline{56.1 \text{ per cent}}$
100 per cent

EXERCISES

In working these exercises, use the table of elements and their atomic weights which you will find in the back of the book.

1. Find the percentage composition of (*a*) table salt; (*b*) lye; (*c*) water; (*d*) sugar.

2. From the following formulas calculate the percentage composition: (*a*) NH_4NO_3; (*b*) $CaSO_4$; (*c*) PCl_5.

3. What is the percentage composition of calcium phosphate?

4. Find the percentage composition of sodium bicarbonate, $NaHCO_3$.

5. What weight of mercury is present in 100 grams of mercuric oxide?

6. Calculate the number of pounds of phosphorus contained in the bones of a man weighing 150 pounds (abbreviated lb). Assume that bones constitute 10 per cent of the weight of the human body and that 58 per cent of the bone tissue is $Ca_3(PO_4)_2$.

7. How many ounces of carbon are present in 1 pound of cane sugar ($C_{12}H_{22}O_{11}$)?

UNIT EXERCISES

1. Write the formulas of these compounds. Try to write them without looking up the valences or writing the valences above the ions.

Lead chloride
Magnesium hydroxide
Ammonium chromate
Calcium bicarbonate
Ferric nitrate
Aluminum sulfate
Ferrous sulfate
Cadmium phosphate
Zinc bromide
Cobalt bromide
Chromium hydroxide
Carbon monoxide
Sulfur dioxide
Bismuth sulfite
Calcium silicate
Sodium oxide
Antimony carbonate
Phosphoric chloride
Phosphorous oxide
Strontium fluoride
Ferric acetate
Aluminum chloride
Potassium bicarbonate
Barium phosphate
Manganic iodide

2. Write the names and formulas of five different compounds containing each of the following ions:

Silver
Mercuric
Ferric
Ammonium
Aluminum
Sulfate
Phosphate
Chloride
Acetate
Nitrate

3. Determine which of the following formulas are correctly written. Write the correct formulas for those which you find to be incorrectly written.

$NaCl_2$
$CaSO_4$
$MgOH_2$
H_3SO_4
HNO_3
HOH
$Ca_2(PO_4)_3$
Na_3PO_4
$CuSO_4$
Sn_2S_4
ZnO
H_2O_2
Sb_3S_2
$CdNO_3$
$NH_4C_2H_3O_2$
IK
K_2ClO_3
Na_2CO_2
SO_2
$AgCN$

REFERENCE FOR FURTHER READING

CAVEN and CRANSTON. *Symbols and Formulas in Chemistry.* Blackie & Son, Ltd., London, 1928.

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UNIT 6

Oxygen

Perhaps the most familiar element to all of us is oxygen. Long before you studied chemistry, you knew that the oxygen of the air was necessary for life. You have known for a long time that air is necessary for ordinary burning and that it is the oxygen which causes this burning. In this unit we will review some of the facts that you already know about oxygen and, in addition, will learn some new facts about this common but very important element.

You may test your knowledge of some important facts about oxygen by trying to answer the questions which follow. Is air a mixture or a compound? How could we secure pure oxygen from the air? How are fish able to breathe in water? Could you smother or drown a fish in water? Are fish able to use the oxygen that is combined with hydrogen in water? Why will a candle soon go out when placed in a closed bottle? What happens to oxygen when it causes coal to burn? The study of chemistry will be most valuable to you in developing your ability to interpret the commonplace things that go on about you. It's fun to know the reasons for things!

PURPOSES TO BE ACHIEVED

1. To understand the part that oxygen plays in maintaining life.
2. To understand burning, rusting, and other commonplace reactions.
3. To gain a knowledge of the chemistry of oxygen, including its properties, preparation, and compounds.
4. To discover the many practical uses of oxygen.

PROBLEMS TO BE SOLVED

1. How are plants and animals dependent upon oxygen?
2. How was oxygen discovered?
3. To what extent does oxygen occur?
4. What are the physical and chemical properties of oxygen?
5. How may pure oxygen be prepared?
6. How has man made practical use of his knowledge of oxygen?

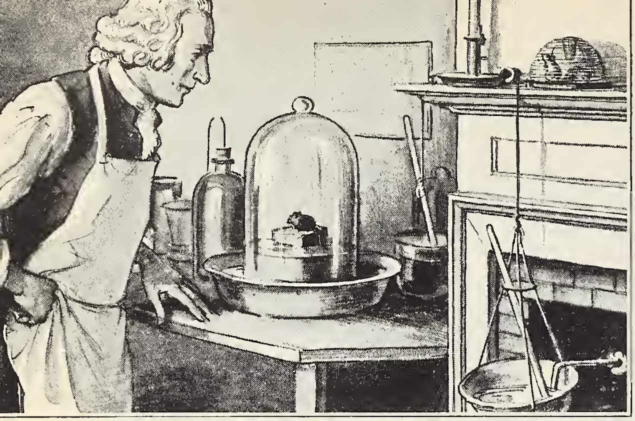
Problem 1. How are plants and animals dependent upon oxygen?

Oxygen helps plants to grow. Most of us know that we must breathe to live, but not all of us are aware that plants also breathe. Scientists have proved that plants absorb oxygen and that if they are deprived of oxygen, they will die. In the growing of plants in chemical solutions without soil, it has been discovered that oxygen must be continually added to the solution. The addition of oxygen has been found necessary to the healthy growth of the plant.

Animals require oxygen. What happens to the oxygen that an animal breathes into its body? Why is oxygen so important to it? Why does it die if oxygen is withheld for only a few minutes? Biologists and chemists are now able to answer these questions and many more like them. To understand how these questions are answered, let us trace the path that oxygen follows through the body. After entering the lungs, it passes through the walls of the tiny blood capillaries and thence into the blood stream. Once in the blood, it combines with the red blood corpuscles, which contain a compound called hemoglobin, thus forming a new compound called oxyhemoglobin. This oxygen-carrying compound is forced to all parts of the body by the heart —to every cell, whether it be located in the brain, muscle, or bone. At the cell the oxygen breaks its combination with the hemoglobin, goes through the cell wall into the cell, and there unites with foodstuffs, such as sugars, proteins, and fats. This chemical union does three things that are necessary if we are to live. First, the chemical reaction liberates heat, which keeps our bodies at a temperature

Ewing Galloway

Aviators flying at high altitudes must be supplied with oxygen to live in the rarefied air, which is deficient in oxygen. Oxygen is supplied to these aviators through the use of special masks, shown here. The cabins of some airplanes are made airtight, so that the oxygen can be released directly into the cabin



Joseph Priestley (1733–1804) proved that mice lived longer in his newly discovered gas (oxygen) than in air

of 98.6° F. Second, it releases energy, which makes possible muscular motion. Third, it enables the body to make new tissue. Moreover, all three of the processes are absolutely necessary if we are to move and function as human machines—in short, to live. In addition to the liberation of energy, the chemical union of oxygen and food results in the formation of water and the gas called carbon dioxide. The carbon dioxide and part of the water are transported back to the heart and lungs via the veins and are expelled to the air as gases. Oxygen traverses a similar path in all animals and serves the same purpose, which we might say is that of making life possible.

Fish have gills instead of lungs, which enable them to absorb the oxygen dissolved in water. For them water is the carrier of this life-giving substance, while for land animals air is the medium which supplies it. But whether the animal lives on land or in water, the oxygen serves the same purpose inside the body.

EXERCISES

1. Why do plants need oxygen?
2. How do the cells of the body obtain oxygen?
3. What use is made of the oxygen received by the cells of the body?
4. What products are eliminated as waste products as a result of the chemical action, in the cells, between food and oxygen?
5. How do fish obtain oxygen?

Problem 2. How was oxygen discovered?

Priestley discovers oxygen. Oxygen was discovered in 1774 by the English chemist Joseph Priestley. It seems peculiar that an element so abundant and so important in combustion should not have been recognized for so long a time. Early peoples tried to explain burning, but they always described it as a supernatural phenomenon. Before the end of the eighteenth century, chemists thought that all substances which would burn contained a substance called *phlogiston.* When a thing burned, they said it was being dephlogisticated. They believed that matter was destroyed when it burned.

Chemistry could not become a true science until the correct explanations of chemical reactions were made. Priestley, in his work on gases, or different kinds of "air," as he called them, finally prepared some pure oxygen in 1774. Although a poor preacher who was considered rather queer because of his unpopular religious beliefs and an absorbing interest in flasks, bottles, and chemicals, this Englishman first prepared pure oxygen by heating red mercuric oxide with a magnifying glass until it decomposed. The chemical reaction which made possible the first preparation is well known today and may be expressed as follows:

$$\begin{array}{c}\text{mercuric oxide} + \text{heat} \longrightarrow \text{oxygen} + \text{mercury}\\ 2\,HgO + \text{heat} \longrightarrow O_2\uparrow^{1} + 2\,Hg\end{array}$$

Antoine Lavoisier, the great French chemist, disproved the phlogiston theory of burning and established the fact that burning is the union of oxygen with a combustible material. He helped to make chemistry an exact science through his invention and use of the analytical balance

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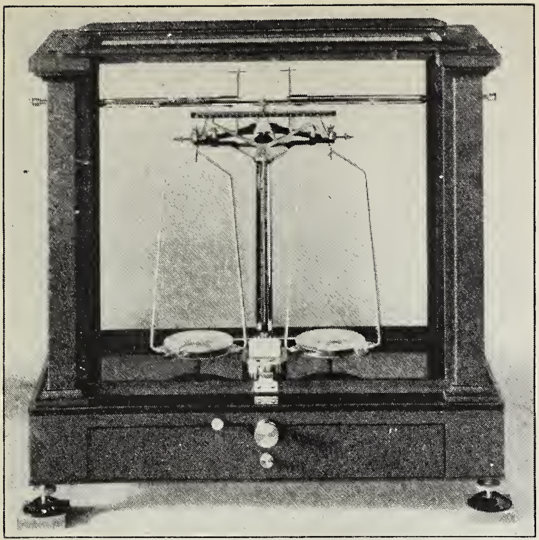
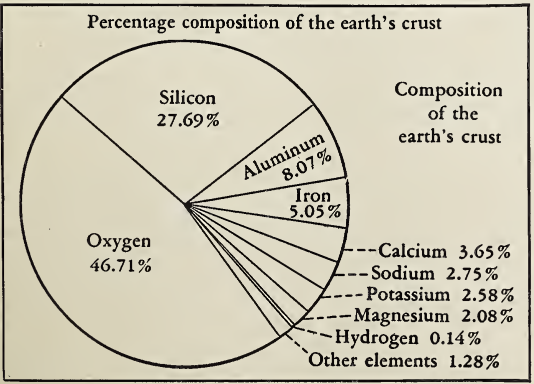
[1] The vertical arrow (↑) is used in a chemical equation to indicate a gaseous substance evolved in the reaction.



William Ainsworth & Sons

An analytical balance is part of the indispensable equipment of a chemical laboratory

Priestley found that substances burned much brighter and faster in this gas than in air. He believed that the gas he discovered was present in air and was necessary for life. To prove this, Priestley placed several mice in jars and sealed the tops. Soon the mice used up all the air and became unconscious. He ran some of the oxygen he had prepared into one of the jars, and the mice soon revived and became active. In the other jars, where none of the gas was admitted, the mice died. Priestley then breathed some of the gas himself and reported that "my breath felt peculiarly light and easy for sometime afterward." He wrote to the French chemist Antoine Lavoisier of his discovery. Lavoisier repeated the experiments of Priestley and gave the newly discovered gas the name of oxygen.



Lavoisier was the first scientist to employ accurate measurements in his experiments. It was he who introduced the analytical balance for use in chemical experimentation. He used it to prove that a substance really gains weight when it is burned.

The experiments of these two pioneer scientists in the latter part of the eighteenth century mark the real beginning of modern chemistry. It was their work which converted chemistry into an exact science.

You should read some of the interesting stories about Priestley and Lavoisier. The references at the close of this unit are very interesting; read them. Why is Lavoisier called the founder of modern chemistry? What methods did he use in his experimental work which converted chemistry into an exact science?

EXERCISES

1. What is the phlogiston theory?

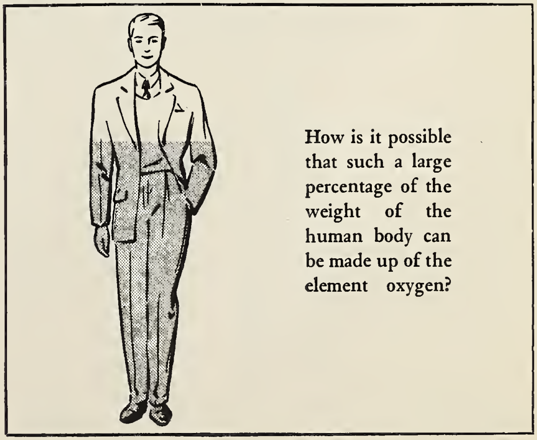
2. Describe the experiments that Priestley performed in his discovery of oxygen.

3. What part did Lavoisier play in the discovery of oxygen?

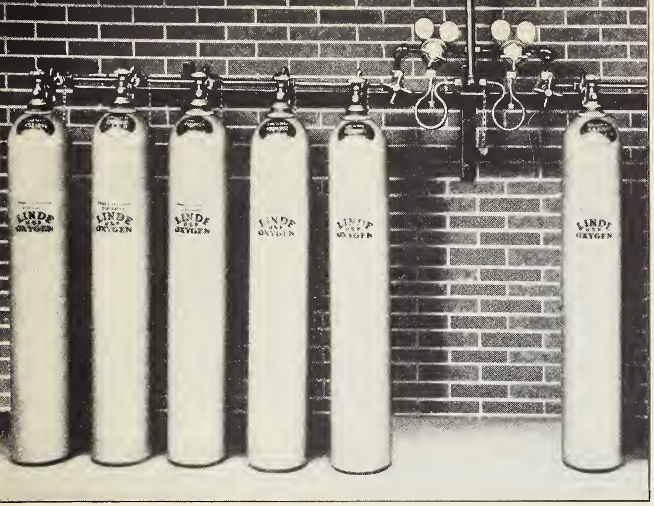
4. How many years has it been since the beginning of modern chemistry?

Problem 3. To what extent does oxygen occur?

Occurrence of oxygen. Oxygen is the most abundant of all the elements. It is found in the free state in air, but is mixed with other gases.



How is it possible that such a large percentage of the weight of the human body can be made up of the element oxygen?



Gases under pressure may be sold for use from steel cylinders

Approximately 21 per cent of the air and 50 per cent of the earth's crust are oxygen, while water is 88.8 per cent oxygen by weight. The human body itself is about 65 per cent oxygen combined with other elements.

The following table gives the approximate composition of air:

Gas	Approximate Composition by Volume
Oxygen	21 per cent
Nitrogen	78 per cent
Argon, neon, krypton, xenon (the rare gases)	00.9 per cent
Carbon dioxide	00.04 per cent
Water vapor	varies

Although the composition of most mixtures is subject to considerable change, air is an exception in that its composition varies but little. Can you suggest ways of proving that air is a mixture and not a compound?

There is a tremendous amount of oxygen in the free state in air, but it also occurs, with other elements, in many natural compounds. It occurs in water, for example, which is the most common and useful compound in nature; and most of the soil and minerals of the world are composed of oxygen combined with other elements.

EXERCISES

1. Name five substances in which oxygen is found in abundance.

2. What is meant by the statement that oxygen is found in the free state in air?

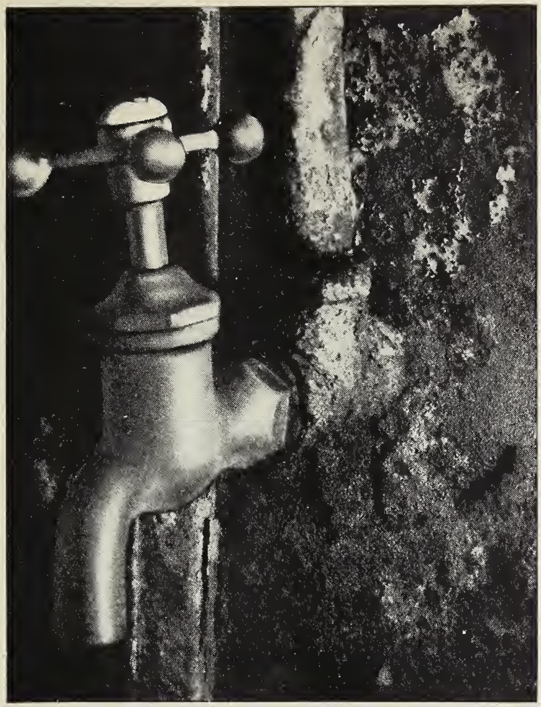
3. Name and give the approximate percentages of the gases found in the air.

Problem 4. What are the physical and chemical properties of oxygen?

Physical properties. Oxygen is a gas at ordinary temperatures. As a matter of fact, it will not liquefy except at extremely low temperatures. The boiling point of liquid oxygen is − 185° C. It is slightly heavier than air, odorless, colorless, and tasteless, and is only slightly soluble in water. (Three parts of oxygen will dissolve in 100 parts of water.) Though the solubility in water is small, it is enough to keep aquatic life in existence. The dissolved air in our drinking water gives it a better flavor and helps to destroy organic impurities. If you will take water from the tap at home or in the laboratory and warm it gradually, you will notice small bubbles of gas forming on the sides of the vessel long before the water boils. This is the dissolved oxygen and other gases being liberated. Why does the heating cause the bubbles to form? How did the oxygen, or air, get into the water? The fact that air is soluble in water is of great importance, and you will become more acquainted with this fact later in your study of chemistry.

Oxygen reacts with substances to form oxides. At ordinary temperatures oxygen will not combine very readily with other substances. For example, an iron nail will unite with oxygen very slowly. If a nail is left exposed to the weather, it will gradually turn into a brown powder. What is the name and formula of this new compound? When metals combine with oxygen, we say that they have been *oxidized.* This reaction is sometimes called corrosion, and the product formed is an *oxide.* Oxidation of this type, which takes place over a long period of time, is called *slow oxidation.*

If we increase the temperature, the activity of oxygen becomes very great. Wood, for instance, will not oxidize very rapidly at ordinary temperatures; but when heated, it will soon burst into a flame, so great is the oxidation. This is *rapid oxidation* and is usually called *combustion* or *burning.* Although oxygen will not burn, it does support combustion. The temperature to which a substance



Keystone

This iron pipe is losing its battle with rust. The faucet is unrusted because it is made of brass

must be raised before it will catch fire and burst into flame is called its *kindling temperature.* When oxygen combines with a substance, heat is given off as one of the products of the reaction. This is very evident when rapid combustion takes place. However, heat is also given off during slow oxidation, but it is given off so slowly that it is not noticeable. If the temperature is high enough, a piece of iron will burn rapidly in pure oxygen, giving off a large quantity of heat and light. Approximately the same amount of heat is given off over a long period of time when a piece of iron of the same size rusts.

Spontaneous combustion due to oxidation. If a substance is insulated or is in a closed place where the heat from slow oxidation cannot be conducted away, the heat gradually accumulates. As the temperature rises, oxidation occurs a little more rapidly, causing heat to be accumulated faster. Finally the kindling temperature of the substance is reached, and it bursts into a flame. This process is called *spontaneous combustion*, and must be guarded against in the home and in industry. Explain why oily rags or rags and brushes containing turpentine, varnish, linseed oil, or paint should not be kept in a closet or box. You have probably read of serious fires starting in flour mills or grain elevators by spontaneous combustion. When grain begins to ferment or to germinate, heat is given off. To prevent the accumulation of this heat in grain elevators, air vents and pipes are arranged to carry it off.

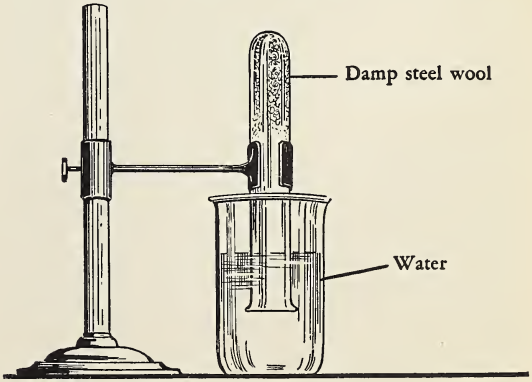
The formula for oxygen in the free state. The oxygen atom does not exist in the free state. In analyzing oxygen and other active gaseous elements, the chemist has discovered that the atoms of these elements always travel in pairs. Therefore the formula for oxygen is written O_2. The oxygen of the atmosphere and the oxygen which you will prepare in the laboratory are in the form of O_2.

Why does the air smell fresh after a thundershower? Have you ever noticed the fresh, pungent odor of the air after a thundershower? The heavy electrical discharges cause some of the molecules of oxygen (O_2) in the air to unite and form larger molecules of oxygen in which there are three atoms combined. This form of oxygen is called *ozone.* Ozone causes the air to smell fresh. It has the formula O_3 and is very unstable. Three molecules of oxygen unite to form two molecules of ozone.

$$\text{oxygen} + \text{energy} \longrightarrow \text{ozone}$$

$$3\,O_2 + \text{energy} \longrightarrow 2\,O_3$$

How can this apparatus be used to demonstrate the slow oxidation of iron?



Ewing Galloway

What kind of oxidation is represented in this picture?

Because ozone is unstable, it is very active and finds a number of uses. It is added to municipal water supplies in Europe to destroy harmful bacteria in the water. Ozone is sometimes liberated into the storage rooms of cold-storage plants to prevent the growth of mold and to deodorize the rooms. It is often used in swimming pools to purify the water. The odor of ozone is sometimes noticeable around electric machines, especially where there is a discharge of sparks. In concentrated form it has a very irritating odor and a blue color. Special electric machines manufacture ozone commercially.

An element may exist in two or more different forms, called *allotropic* forms. Ozone is an allotropic form of oxygen. Sulfur, carbon, and phosphorus are other elements having allotropic forms.

Oxygen forms many oxides. As the earth cooled from its molten state millions of years ago, many compounds were formed. Oxygen, being very active at high temperatures, naturally combined with many other elements and formed oxides. For this reason, a large percentage of the ores of our most useful metals occur as oxides. Our most valuable metal, iron, is obtained principally from two oxides, hematite (Fe_2O_3) and magnetite (Fe_3O_4). Sand (SiO_2) is an oxide of silicon. As the earth cooled, the hydrogen united with the oxygen to form steam, which later condensed as water to fill the oceans. Oxygen combines with more elements than any other element.

Do compounds other than oxides contain oxygen? Look at the lists of radicals on page 49, and

U. S. Bureau of Mines

Spontaneous combustion in this starch mill caused the death of forty-two men

you will find that most of them contain oxygen. The compounds that contain these radicals, then, must contain oxygen. The properties and uses of many compounds containing oxygen will be studied all through this course in chemistry.

Compounds that liberate oxygen. Many oxygen-containing compounds, such as nitrates and chlorates, liberate oxygen rather easily. When oxygen is first formed from these compounds, it is called *nascent* ("newborn") oxygen; it is still in the atomic state (O) and is much more active than molecular oxygen (O_2). If there is a substance present with which this nascent oxygen will combine, oxidation takes place; if not, the oxygen is liberated as ordinary O_2.

EXERCISES

1. List the physical properties of oxygen.
2. What causes boiled water to taste "flat"?
3. What causes iron to rust?
4. Is oxygen an active element? Why or why not?
5. What is an oxide?
6. What causes burning?
7. What is meant by "kindling temperature"?
8. Through the use of an illustration tell how spontaneous combustion takes place.
9. What is ozone? How is it produced?
10. What uses are made of ozone?
11. What is an allotropic element? Give an example.
12. Why are there so many oxides in the earth's crust?
13. Of what value are these oxides which are found in the earth?
14. What is nascent oxygen?

Problem 5. How may pure oxygen be prepared?

Laboratory methods. In the laboratory you will prepare pure oxygen in several ways. The method used by Priestley and Lavoisier when they prepared oxygen for the first time is still being used in the laboratory. You will recall that this method involved the heating of mercuric oxide.

A method more generally used for the preparation of large quantities of oxygen in the laboratory is that of heating potassium chlorate. If you heat $KClO_3$ in a test tube to a fairly high temperature, some decomposition takes place, with oxygen given off as one of the products. The addition of another chemical, manganese dioxide (MnO_2), to the $KClO_3$ causes the reaction to take place much more rapidly, though the manganese dioxide undergoes no change. A substance which will either increase or decrease the speed of a chemical reaction without undergoing a permanent change itself is called a *catalyst* or *catalytic agent.*

The reaction for obtaining oxygen from $KClO_3$ may be expressed by an equation:

$$\text{potassium chlorate} + \text{manganese dioxide} + \text{heat} \longrightarrow \text{potassium chloride} + \text{oxygen} + \text{manganese dioxide}$$

$$2\,KClO_3 + MnO_2 + \text{heat} \longrightarrow 2\,KCl + 3\,O_2\uparrow + MnO_2$$

The MnO_2 undergoes no permanent change. Where, then, does the oxygen come from?

Oxygen may be prepared by heating lead peroxide:

$$\text{lead peroxide} + \text{heat} \longrightarrow \text{lead monoxide} + \text{oxygen}$$

$$2\,PbO_2 + \text{heat} \longrightarrow 2\,PbO + O_2\uparrow$$

This means that two molecules of lead peroxide decompose upon heating, with the formation of two molecules of lead monoxide and one of oxygen.

In this equation, notice that the oxygen is written with two atoms in the molecule. We must always write oxygen O_2 when it is in the free state, since the molecule contains two atoms. The reason for this is that in the free state oxygen has six electrons and two vacant spaces in the outer orbit. There is a tendency for it to complete this orbit. If it can secure the electrons from some other element, it will unite with it to form a compound. If there are no other elements present from which it can secure these electrons, two of its atoms go together and share their electrons. For this reason, oxygen in the free state usually exists with two atoms in the molecule. Other gases which contain two atoms in the molecule are H_2, N_2, Cl_2, Br_2, and I_2.

Still another method sometimes used in the laboratory to prepare oxygen is that of treating sodium peroxide with water. The equation for this reaction is as follows:

$$\underset{\text{peroxide}}{\text{sodium}} + \text{water} \longrightarrow \underset{\text{hydroxide}}{\text{sodium}} + \text{oxygen}$$

$$2\,Na_2O_2 + 2\,H_2O \longrightarrow 4\,NaOH + O_2\uparrow$$

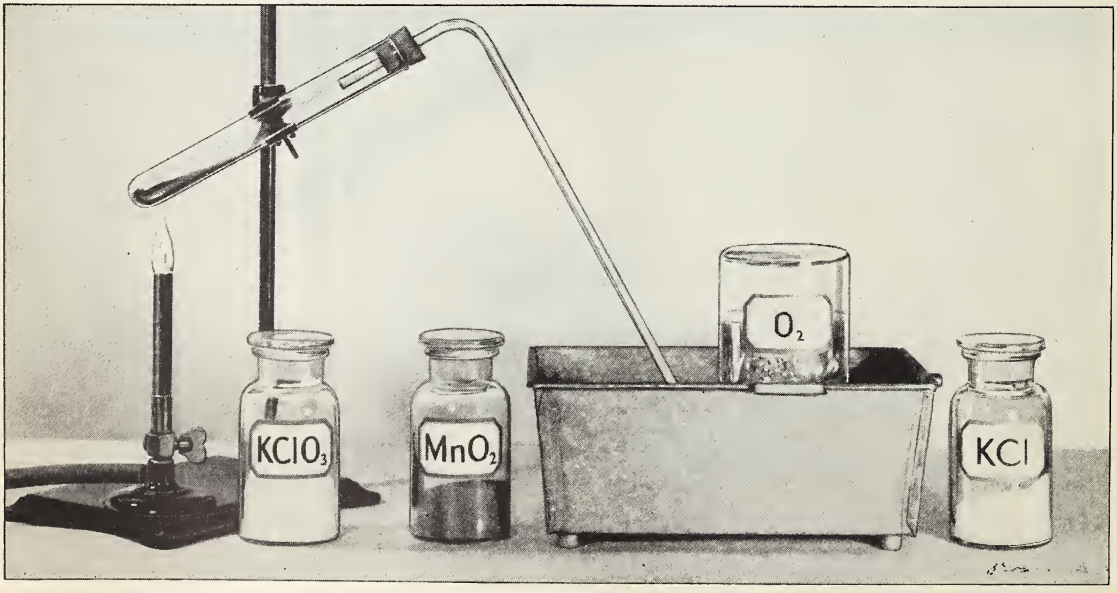
Commercial methods. Since pure oxygen is so much more concentrated than that in the air, it has many uses. It is usually prepared for commercial use by either of two methods: (1) by the fractional distillation of liquid air; (2) by the electrolysis of water.

When oxygen is prepared from air, the air must first be liquefied. To accomplish this, the air is alternately compressed and cooled until a high pressure is reached. The gas is then allowed to expand, causing further cooling, which finally results in the liquefaction of the air.

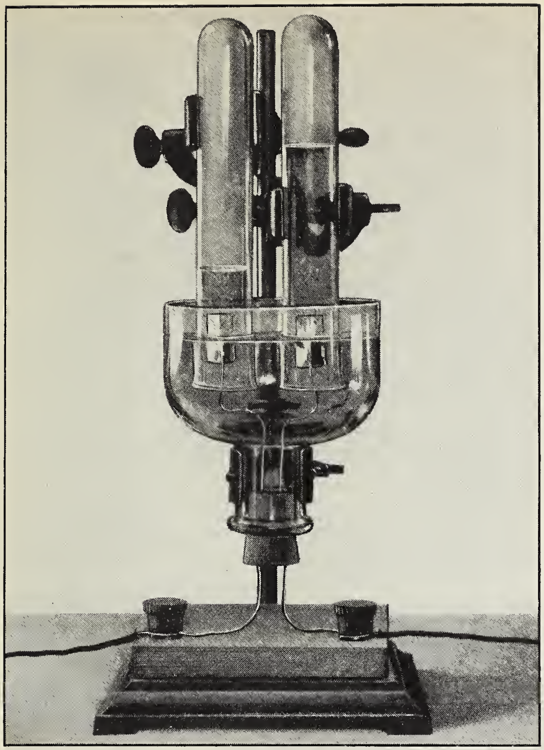
Liquid air obtained in this manner is a mixture largely of liquid oxygen and nitrogen. When the temperature of the liquid air is allowed to rise, the nitrogen boils off first at its boiling temperature of – 198° C, leaving oxygen in its liquid state. The liquid oxygen then changes into a gas at its boiling temperature of – 185° C and is pumped under pressure into tanks or cylinders. The oxygen thus obtained is very pure and has many commercial uses.

Neon and argon are also obtained from liquid air in a similar manner. In recent years these gases have been widely used in electric lighting.

Another cheap source of oxygen is water. The process of passing an electric current through water



Oxygen is prepared in the laboratory by heating a mixture of potassium chlorate and manganese dioxide. What products are formed in the reaction?



Water may be decomposed into oxygen and hydrogen in the laboratory by the use of the apparatus shown in this drawing. Acid is placed in the water to aid in conducting the electric current

to obtain oxygen has found wide commercial use. The electric current causes the water to break up into its two component elements. Very briefly, the process is this: A positive and a negative electrode, connected with a direct electric current, are placed in the water. The hydrogen is collected at the negative electrode and the oxygen at the positive electrode.

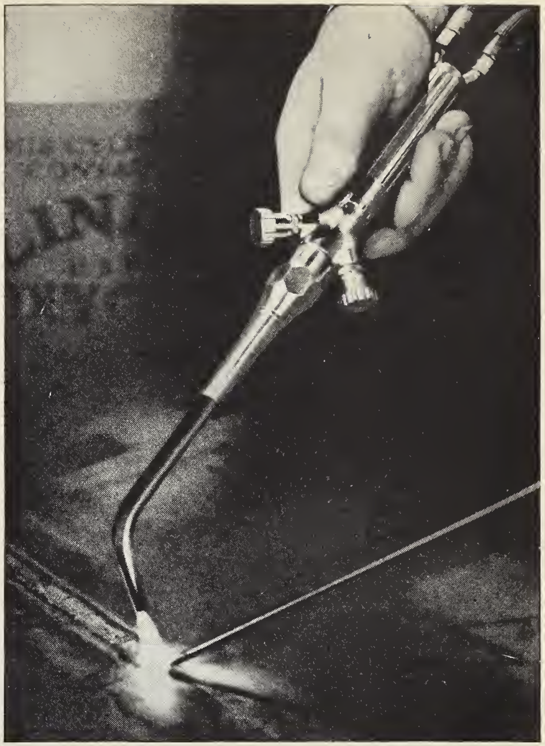
The chemical equation for this reaction is as follows:

$$\text{water} + \text{electrical energy} \longrightarrow \text{hydrogen} + \text{oxygen}$$
$$2\,H_2O + \text{electrical energy} \longrightarrow 2\,H_2\uparrow + O_2\uparrow$$

EXERCISES

1. Name, describe, and write equations for three laboratory methods of preparing oxygen.

2. What is a catalyst?



Linde Air Products Company

Pieces of metal may be welded together by the use of the oxyacetylene torch

3. Describe the process of obtaining oxygen from the air.

4. Explain the method and write the equation for the preparation of oxygen by the electrolysis of water.

5. What gases, other than oxygen, are obtained from liquid air?

Problem 6. How has man made practical use of his knowledge of oxygen?

Oxygen is a useful element. You are familiar with the fact that the oxygen in the air is necessary in breathing and in the burning of fuel. In the pure state oxygen is sold in cylinders to hospitals to provide oxygen for patients having respiratory diseases such as pneumonia. The patient is placed under a tent, and the oxygen is supplied under controlled conditions. Where a few years ago many persons who were overcome through suffocation and drowning were never revived, it is now possible to save many lives through the administering of oxygen.

Practically every city and village now has an oxygen inhalator ready for emergency use. Garages buy oxygen to mix with another gas, acetylene, to produce a very hot flame for welding metals. Fish are kept alive while being transported by bubbling oxygen into the water with a diffuser. Aviators and mountain-climbers often carry oxygen tanks when ascending to high altitudes. Sometimes the engines of airplanes are connected with oxygen superchargers. Rescue workers in mine explosions often wear masks which provide pure oxygen.

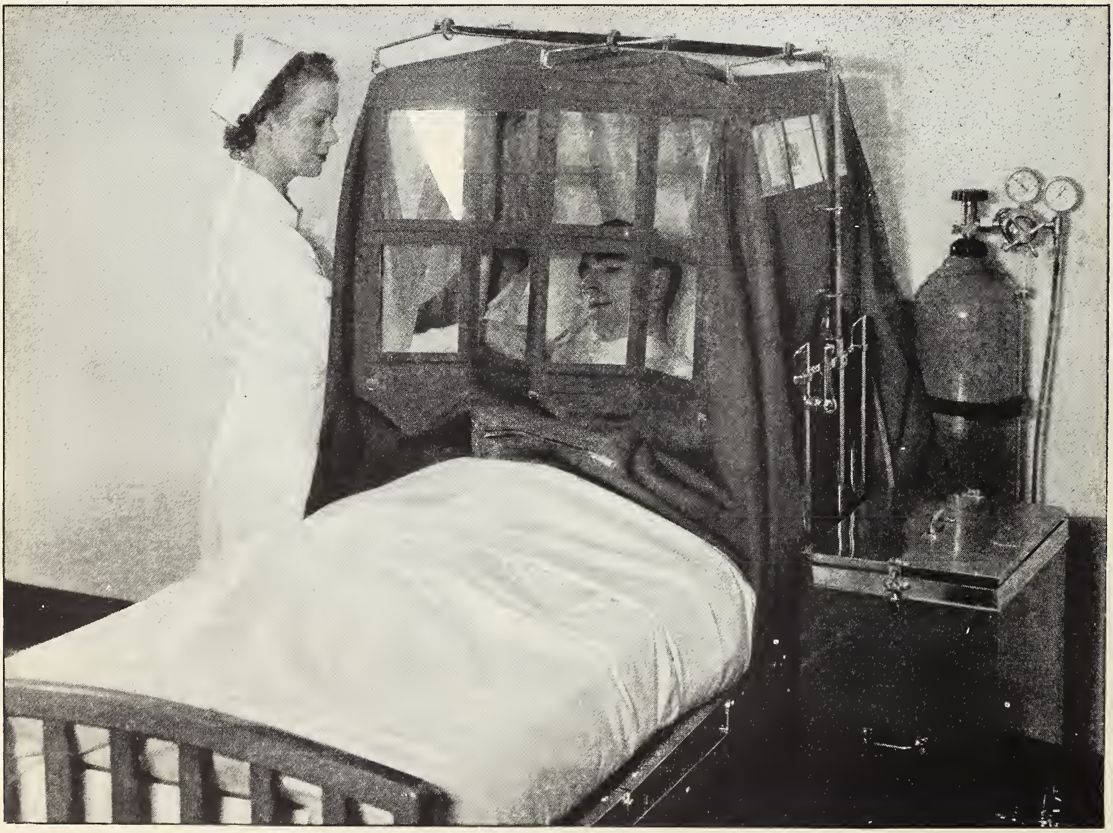
You will be able to find much material on oxygen in the library. You should also search for information on the history of oxygen and the part that it has played in the development of our present civilization. Probably no element contributes so much either directly or indirectly to man as oxygen does.

In addition to these uses, oxygen means much to you in a personal way. Pure fresh air, containing the necessary amount of oxygen, is essential to happy healthful living. A part of the problem confronting air-conditioning engineers is that of maintaining the correct amount of oxygen in homes and public buildings. However, you may assure yourself of getting enough pure oxygen by spending as large a portion of the day as possible in the great out-of-doors in healthful exercise and play.

This completes a series of problems on oxygen. However, throughout your entire study of chemistry, you will be learning about compounds of oxygen. Many of these compounds contain another important element, called hydrogen. This element is of such importance that the following unit will be devoted to it.

Why is oxygen often administered to patients in hospitals?

Linde Air Products Company



EXERCISES

1. What uses are made of oxygen in hospitals?
2. How is oxygen used in industry?
3. Why is oxygen necessary for animal life?
4. Is everyone assured of sufficient oxygen for healthful living?
5. Make a list of the uses of oxygen.

UNIT EXERCISES

Select the correct word, group of words, or sentence which completes each of the following statements, and write its letter on a separate sheet of paper. In some cases there may be more than one correct answer.

1. Air is (*a*) a mixture (*b*) an element (*c*) a compound (*d*) a compound of oxygen.

2. Fish can live in water because (*a*) they do not need the oxygen of air to live (*b*) they use the oxygen which is united with the hydrogen in H_2O (*c*) they are able to remove the dissolved oxygen from the water (*d*) they do not need oxygen.

3. When coal in a furnace burns, (*a*) the gas from the coal unites with the carbon to give off heat (*b*) the oxygen of the air combines with the coal gas and carbon to give off heat and oxides of carbon (*c*) black visible smoke must be one of the products (*d*) oxidation has taken place.

4. Oxygen is necessary to all animal life because (*a*) all animals breathe (*b*) plants too must have it (*c*) it is necessary in the burning of foodstuffs (*d*) it is found in the air.

5. The discovery of oxygen marks the beginning of modern scientific progress because (*a*) it exploded the phlogiston theory of burning (*b*) the true explanation of burning became known (*c*) oxygen did not exist in the free state before that time (*d*) this was the first chemical experiment which was performed.

6. It is estimated that the percentage of oxygen in the earth's crust is (*a*) 21 per cent (*b*) 88.8 per cent (*c*) 50 per cent (*d*) 78 per cent.

7. Four fifths of the air is (*a*) oxygen (*b*) hydrogen (*c*) carbon dioxide (*d*) nitrogen (*e*) water vapor (*f*) rare gases.

8. Some of the important physical properties of oxygen are that (*a*) it supports life (*b*) it is soluble in water (*c*) its density in the gaseous state is about the same as that of air (*d*) its liquefying point is $-185°$ C (*e*) it causes things to burn.

9. Some of the important chemical properties of oxygen are that (*a*) it is very compressible (*b*) it is very active at ordinary temperatures (*c*) it burns readily (*d*) it unites with more elements than any other substance (*e*) it forms stable compounds (*f*) it supports combustion.

10. Some examples of spontaneous combustion are (*a*) the explosion of a steam boiler (*b*) the explosion of dynamite (*c*) fires starting from oily rags in closets or other places where there is little circulation of air (*d*) the burning of a stack of freshly cut hay.

11. Oxidation is the chemical process that takes place when (*a*) the valence of an element is increased (*b*) oxygen unites with any other element (*c*) water is changed to steam (*d*) things burn.

12. If one were asked to prepare some oxygen in the laboratory, he would select the following way: (*a*) Liquefy some air and boil off the nitrogen. (*b*) Heat some potassium chlorate with some manganese dioxide. (*c*) Heat iron oxide in a test tube. (*d*) Heat mercuric oxide in a test tube.

REFERENCES FOR FURTHER READING

Foster, William. *The Romance of Chemistry.* D. Appleton-Century Company, New York, 1936.

Holmes, Harry N. *Out of the Test Tube.* Ray Long & Richard R. Smith, Inc., New York, 1934.

Hydrogen

Hydrogen is the lightest and the most simple in structure of all the 92 elements; yet it is one of the most important. This interesting gas has many important uses which you should know about. Moreover, its compounds are related to man's daily living in countless ways. Water, the universal solvent, which quenches our thirst, protects our homes from fire, and helps to make our fields green, is a compound containing the two gaseous elements oxygen and hydrogen. We have learned that oxygen makes things burn, and we shall learn in this unit that hydrogen is an element which burns with the hottest known flame; yet when these elements are combined, they form water, which puts out fire. Seven eighths of the earth's surface is covered by water, and yet the element hydrogen was not discovered by man until 1766. As early as the sixteenth century, bubbles of a gas had been noticed to come from pieces of iron when dropped in sulfuric acid. No attempt was made to collect the gas and ascertain its properties until Lord Cavendish tried putting various metals in both sulfuric acid and hydrochloric acid. You may imagine his surprise to find that when the gas burned with oxygen, water was formed. He believed that the new gas came from the metals, as it appears to do. We know now that it comes from the acid. Lavoisier, the French chemist, was impressed by the properties of the new gas and called it hydrogen, "producer of water."

PURPOSES TO BE ACHIEVED

1. To learn how to identify hydrogen.
2. To learn how hydrogen is prepared.
3. To discover the practical uses of hydrogen.

PROBLEMS TO BE SOLVED

1. Where is hydrogen found?
2. What are the physical and chemical properties of hydrogen?
3. How may hydrogen be prepared?
4. How has man used the scientific knowledge of hydrogen to make better the life he lives?

Problem 1. Where is hydrogen found?

Sources of hydrogen. While oxygen occurs free in nature, hydrogen does not occur in the free state except in minute traces. Probably it did exist in the free state when the earth was in the gaseous or molten state, as many metals will react with water when extremely hot to form hydrogen. However, though hydrogen does not occur in the free state, its compounds are found widely distributed in nature. For example, you have learned that hydrogen is a

Henry Cavendish (1731–1810) was a wealthy, eccentric Englishman. He spent most of his life closeted in his well-equipped laboratory, delving into the secrets of nature. He collected hydrogen, which he called "inflammable air," described its properties, and showed that it produced water when burned

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part of water. You will soon discover that it is found in the body tissue of all animals, in plant cells, and in most organic compounds, such as petroleum and natural gas. It is estimated that there are 15 pounds of hydrogen in the body of a 150-pound man. Notice that hydrogen is found in the following compounds: $C_{12}H_{22}O_{11}$ (sugar), $C_{10}H_{16}$ (turpentine), and $C_6H_{10}O_5$ (starch).

EXERCISES

1. What are some compounds which contain hydrogen?

2. What is the approximate amount of hydrogen in your body?

3. What do we mean when we say that hydrogen does not exist in the free state?

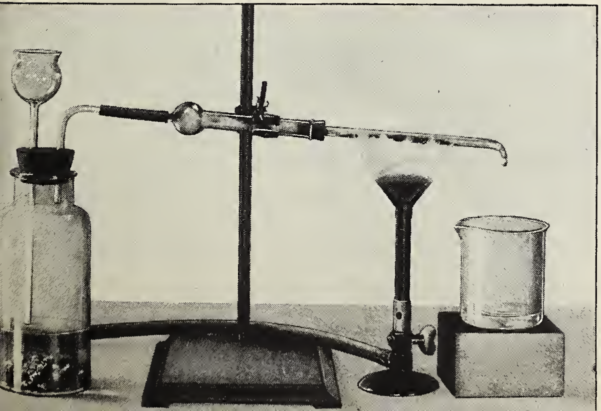
Problem 2. What are the physical and chemical properties of hydrogen?

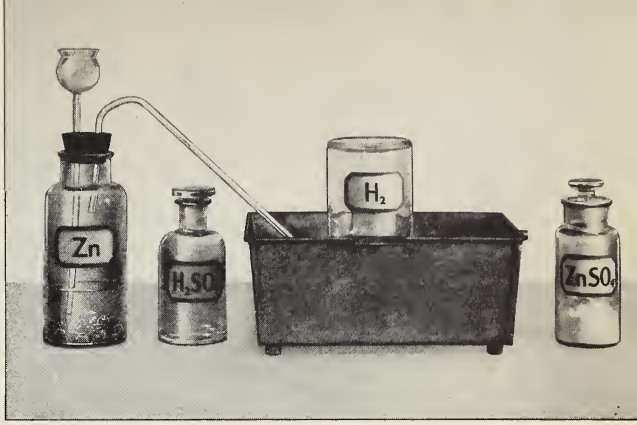
How hydrogen is identified. Hydrogen is a colorless, odorless, and tasteless gas, only very slightly soluble in water. It is the lightest of all the elements, 1 liter (abbreviated l) weighing only .089 grams.

Chemically hydrogen is rather inert at ordinary temperatures. Hydrogen is very combustible. When mixed with oxygen, hydrogen may be ignited easily by a spark. It unites with oxygen to form a molecule of water (H_2O). The chemical equation for this reaction follows:

$$\begin{array}{ccccc}\text{hydrogen} & + & \text{oxygen} & \longrightarrow & \text{water}\\ 2\,H_2 & + & O_2 & \longrightarrow & 2\,H_2O\end{array}$$

Explain how copper oxide is reduced in this experiment. What are the products of the reduction? What is the purpose of the calcium chloride?





Hydrogen gas may be prepared by the action of sulfuric acid on zinc. What is the other product of this reaction?

When a stream of hydrogen is passed over the oxides of some metals at a high temperature, it combines with the oxygen to form water and a metal. For example, when hydrogen is passed over heated copper oxide, the products resulting are metallic copper and water. The following equation illustrates this reaction:

$$\begin{array}{ccccccc}\text{copper oxide} & + & \text{hydrogen} & \longrightarrow & \text{copper} & + & \text{water}\\ CuO & + & H_2 & \longrightarrow & Cu & + & H_2O\end{array}$$

Such a reaction, in which the oxygen is taken away from a compound, is called *reduction.* The copper oxide is said to be *reduced*, and the hydrogen is the *reducing* agent. The reducing property of hydrogen is one of its most important chemical properties. Later you will discover that the term *reduction* has a much broader meaning.

EXERCISES

1. What are the physical properties of hydrogen?

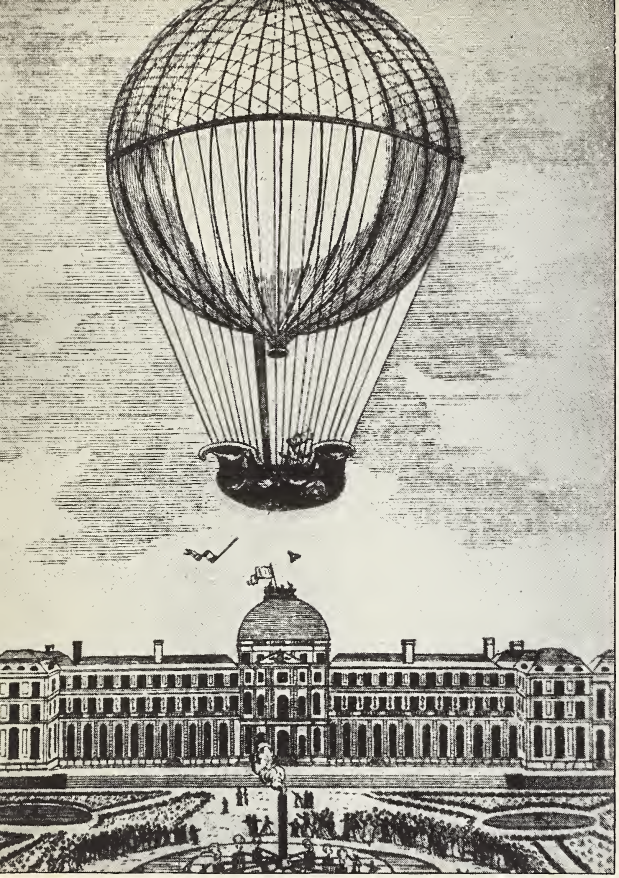
2. State two chemical properties of hydrogen.

3. Explain what is meant by the statement that hydrogen is a good reducing agent.

4. In the reduction of CuO with H_2, what prevents the hydrogen from exploding?

Problem 3. How may hydrogen be prepared?

Hydrogen and the activity series. Hydrogen has a positive valence when it unites with other elements, and in this respect it is like the metallic elements. The hydrogen of water and acids may be displaced by metals which are chemically more active than it. The table on page 66 shows an arrangement of some of the common metals with



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The ascent of Charles and Robert in their hydrogen balloon on December 1, 1783, at Versailles. After a contemporary drawing

hydrogen, according to their chemical activity. Such an arrangement of elements is called the displacement or activity series. In this series, any metal will displace any other metal below it from solutions of its inorganic compounds. Those metals which are high in the series are very active, while those which are low are inactive. Hydrogen occurs rather low in the series, and therefore any of the metals above it will displace it from its compounds. The very active metals, such as potassium, sodium, and calcium, will displace it from water at ordinary temperatures. Red-hot iron will displace hydrogen from steam. The metals close to hydrogen in the series will displace it from acids. The displacement of hydrogen from its inorganic compounds by metals is commonly used as a method of preparing the gas.

Displacement, or Activity, Series of Common Metals

Potassium
Calcium
Sodium
Aluminum
Zinc
Chromium
Iron
Tin
Lead
Hydrogen
Copper
Mercury
Silver
Platinum
Gold

Laboratory preparation of hydrogen from water and from an acid. You will make hydrogen by placing a small piece of sodium on water. The reaction that takes place is as follows:

$$\overset{\text{sodium}}{2\,Na} + \overset{\text{water}}{2\,HOH} \longrightarrow \overset{\text{sodium hydroxide}}{2\,NaOH} + \overset{\text{hydrogen}}{H_2\uparrow}$$

A general method for the preparation of hydrogen in the laboratory is to place a less active metal, but one above hydrogen in the displacement series, in a dilute solution of a strong acid. Hydrochloric or sulfuric acid is generally used. Nitric acid is not used, because it is a strong oxidizing acid and the hydrogen that is formed is immediately oxidized to form water. Concentrated H_2SO_4 acts similarly. Zinc is the metal most commonly used in preparing hydrogen in this way. An example of this type of reaction is shown in the following equation:

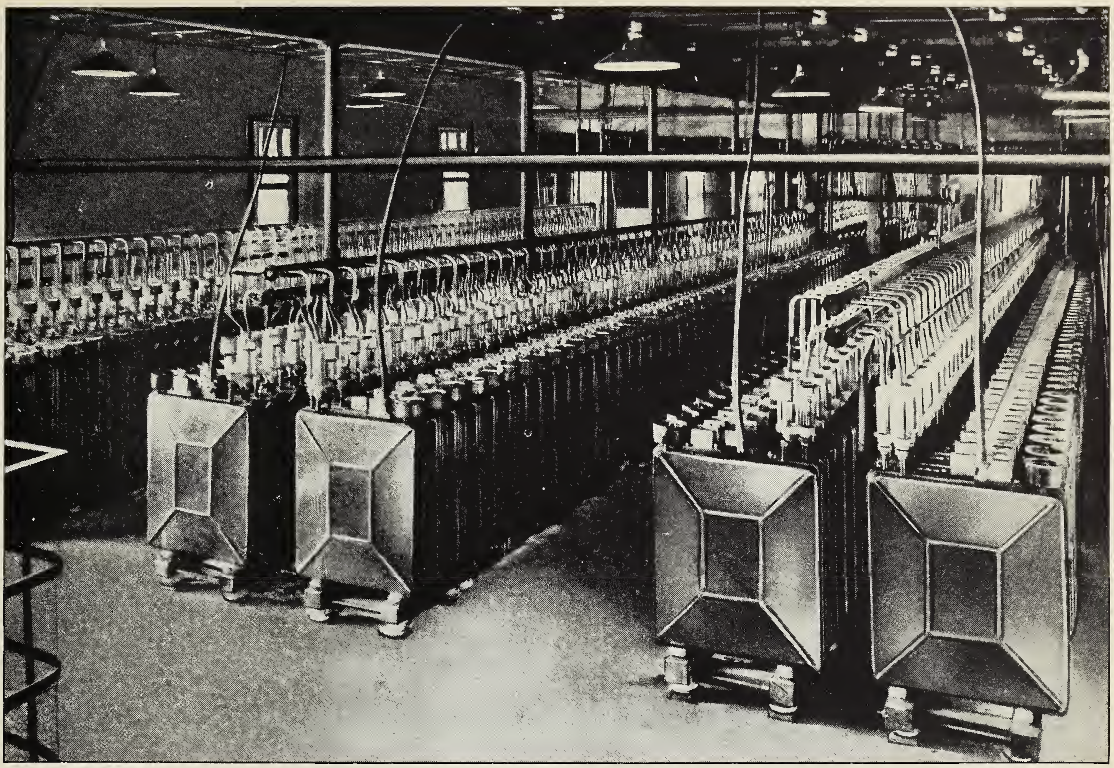
$$\overset{\text{zinc}}{Zn} + \overset{\text{sulfuric acid (dilute)}}{H_2SO_4} \longrightarrow \overset{\text{zinc sulfate}}{ZnSO_4} + \overset{\text{hydrogen}}{H_2\uparrow}$$

Commercial preparation. Most hydrogen is produced commercially by the electrolysis of water or by passing steam over red-hot iron or hot coke. It is also obtained as a by-product in the manufacture of lye. The latter process will be explained later. The method of obtaining hydrogen by the electrolysis of water was described on page 60. Since a molecule of water contains two atoms of hydrogen and only one atom of oxygen, the process will yield twice as much hydrogen by volume as oxygen.

The following equation represents the making of hydrogen by passing steam over hot coke:

$$\overset{\text{steam}}{H_2O} + \overset{\text{coke}}{C} \longrightarrow \overset{\text{carbon monoxide}}{CO} + \overset{\text{hydrogen}}{H_2\uparrow}$$

Both carbon monoxide and hydrogen burn with hot flames, and this mixture, called water gas, is used as a fuel by some industries and by some cities. If the hydrogen is desired in a pure form, the mixture of the gases is chilled until the carbon monoxide solidifies, leaving pure hydrogen.



Gas Industries Company

A plant where hydrogen and oxygen are produced by the electrolysis of water. The tubes running from each electrolytic cell carry oxygen and hydrogen to storage tanks

EXERCISES

1. Where does hydrogen occur in the displacement series?

2. Explain what is meant by the activity series.

3. What is meant by the statement that sodium is more active than copper?

4. Could you obtain pure silver from silver nitrate solution by putting pieces of copper in the silver nitrate solution?

5. Review Unit 6 and write word and formula equations for the electrolysis of H_2O.

6. Could you prepare hydrogen by placing iron in HNO_3? in HCl? Why or why not?

Problem 4. How has man used the scientific knowledge of hydrogen to make better the life he lives?

Uses of hydrogen. The first flight in a hydrogen balloon was made by Charles and Robert in 1783 near Paris. This experiment was a success because of the accurate reasoning that hydrogen was less dense than air and that a bag of hydrogen should be buoyed up in the atmosphere just as cork is buoyed up in water. The giant dirigibles which have crossed the ocean have usually been filled with hydrogen because of its extreme relative lightness. Helium is gradually replacing hydrogen for this purpose because, in addition to having a lower density than air, it is also noncombustible, whereas hydrogen is highly combustible. The production of helium is confined to the United States and controlled by the United States government; therefore its use is not world-wide.

Because it burns with such a hot flame, hydrogen is sometimes used to cut metals. The oxyhydrogen blowtorch and the atomic hydrogen torch produce flames of extremely high temperature which are sufficient to cut right through metal bars and plates.

Another use of hydrogen with which you should be familiar involves the use of the chemical formulas for the hydrogen compounds in cottonseed oil. Sometimes you may wonder how the knowledge of the molecular formulas of compounds can be of much importance. The description of how solid cooking fats were first made will help to explain their importance. The cottonseed-oil refineries were faced with the problem of disposing of the oil extracted from cottonseed. The oil itself was sold in jugs for cooking purposes to people in the cotton-producing states, but most people prefer a cooking fat which is solid and white like lard. When cottonseed oil was analyzed, it was found to be principally a substance with the molecular formula $(C_{17}H_{33}COO)_3C_3H_5$. Chemists readily saw the similarity between this formula and that of the chief component of lard, stearin, $(C_{17}H_{35}COO)_3C_3H_5$. The only difference between these two formulas is that stearin contains six atoms more of hydrogen than cottonseed oil contains. The chemists working on this problem then tried to put six more atoms of hydrogen in the cottonseed-oil molecule. No matter how much hydrogen was forced into the oil, it bubbled out again. Finally they brought in the services of a catalytic agent and succeeded in causing the union of the hydrogen with the molecules of the cottonseed oil. The catalyst sometimes used is a form of finely divided nickel. This process is called hydrogenation, and the hydrogenated cottonseed oil is sold as a vegetable compound under the trade names "Crisco," "Snowdrift," etc. The newest development along this line is the hydrogenation of lard to make it whiter and firmer.

Hydrogen may be combined with nitrogen of the air in the presence of the catalyst platinum (Pt) to form synthetic ammonia (NH_3). This process, known as the Haber process, was developed just before the first World War for use in the making of explosives. Ammonia produced in this way is now used in making fertilizers. The ammonia may be converted into nitric acid by another process, which you will study later. The equation for the Haber reaction is as follows:

$$\begin{array}{ccc} \text{nitrogen} + \text{hydrogen} & \xrightarrow{\text{catalyst}} & \text{ammonia gas} \\ N_2 + 3\,H_2 & \xrightarrow[\text{(Pressure, high temperature)}]{Pt} & 2\,NH_3 \end{array}$$

Another important use of hydrogen is in the manufacture of methyl alcohol, or methanol. Hydrogen is combined with carbon monoxide under suitable conditions. The equation for the reaction is as follows:

$$CO + 2\,H_2 \longrightarrow CH_3OH$$

Recently it has been found possible to hydrogenate many of the products of crude oil to make gasoline. In addition, chemists have perfected a process for the hydrogenation of coal to produce gasoline and other liquid fuels.

The most useful compound of hydrogen is water. You have undoubtedly noticed that hydrogen is the constituent of many compounds, the most important of which is water. In addition to being a most useful compound in maintaining life, water is essential in the chemistry laboratory. In fact, water is so important to chemistry that some knowledge of it is necessary for an understanding of everything we shall study.

The next unit will deal with an important application of water to chemistry—namely, solutions. In other units you will learn about water as it relates to the individual, the home, and the community.

EXERCISES

1. What is the weight of a liter of H_2?

2. Why is it dangerous to use hydrogen in balloons and dirigibles?

3. Contrast the chemical and physical properties of hydrogen and helium.

4. List the uses of hydrogen. Describe how each use affects your life.

5. How does the formula for the principal ingredient of cottonseed oil differ from the formula for stearin?

6. Explain what is meant by the process known as hydrogenation. Is it a chemical process or a physical one?

UNIT EXERCISES

1. In the following exercise Group I contains incomplete statements or words, and Group II contains phrases or words which, when properly matched with the incomplete statements or words in Group I, make true statements. You are to match the two groups so that you will have a set of true statements. For example, if the first incomplete statement in Group I is correctly completed by 7 in Group II, you will write, on a separate piece of paper, 1 and 7.

Group I

1. The least dense gas is
2. The oxyhydrogen blow torch produces
3. The hydrogen of acids is
4. Hydrogen is a reducing
5. Hydrogen
6. Hydrogen was discovered by
7. Hydrogen may be produced by
8. The word *hydrogen* means
9. A substance which changes the speed of a chemical reaction is called
10. "Crisco" is made by

Group II

1. agent.
2. a catalyst.
3. helium.
4. supports combustion.
5. is combustible.
6. displaced by active metals.
7. hydrogen.
8. an oxidizing agent.
9. Priestley.
10. a very hot flame.
11. adding zinc to concentrated nitric acid.
12. passing steam over red-hot iron.
13. an acid.
14. "producer of water."
15. Cavendish.
16. hydrogenation of cottonseed oil.

2. In making hydrogen for balloons, sometimes scrap iron is treated with dilute hydrochloric or sulfuric acid. Write the word equation for the reaction that takes place, assuming that the iron becomes a ferrous compound during the reaction.

3. You may wish to buy a toy rubber balloon and fill it with hydrogen made in the laboratory. What are the factors which would limit the height to which such a balloon would ascend?

4. Sometimes lard-manufacturers take a yellow lard and add hydrogen to it in the presence of a catalytic agent. What is the purpose of this process?

5. Explain why water gas produces a very hot flame.

6. Write the equations for the burning of water gas.

7. When a person inhales purified hydrogen and talks as he exhales it, his voice is much higher in pitch than normal. Can you give an explanation based upon some physical property of hydrogen which might account for this?

8. Determine the molecular weight of a molecule of stearin (lard). Remember that the weight of a molecule equals the total weight of all the atoms which compose it.

9. Write the equation for the commercial preparation of hydrogen by the electrolysis of water. Why is this process used near Niagara Falls?

10. Explain why a bottle filled with hydrogen does not explode violently, while a bottle half filled with hydrogen does explode violently.

11. Describe how you could prove that hydrogen is less dense than air.

REFERENCES FOR FURTHER READING

Foster, William. *The Romance of Chemistry.* D. Appleton-Century Company, Inc., New York, 1936.

Kendall, James. *At Home among the Atoms.* D. Appleton-Century Company, Inc., New York, 1929.

UNIT 8

Solutions and Ionization

We live in a world of solutions. Our bodies function in a multitude of different solutions. The industrial processes in most of our manufacturing plants are possible because of a knowledge of solutions. Yet most people do not know what a solution really is. The main purpose of this unit is to give you this knowledge and to enable you to grasp the significance of the opening sentence.

Whenever you take a drink of water, you are really drinking a solution which is a mixture of various minerals, gases, and water. When you add sugar and milk to your coffee or tea, you are making a solution. You are able to remove spots from your clothing because someone discovered that the substances which cause the spots are soluble in some material such as gasoline.

Perfume is a solution. Antifreeze in your automobile is a solution, and so is the gasoline that you use in it. Moreover, the digestive juices in your stomach are solutions, as is also the blood which flows through your arteries and veins. Solutions are so important that many of the most important facts about them will have to be learned at this time; and you will be studying many interesting things about them throughout the rest of this book.

PURPOSES TO BE ACHIEVED

1. To develop an appreciation of the part that solutions play in our daily lives.
2. To understand the true chemical nature of solutions.
3. To understand how solutions and ionization aid in explaining chemical reactions.

PROBLEMS TO BE SOLVED

1. What is a solution?
2. How may the speed of solution be increased?
3. What are the kinds of solutions?
4. What factors affect the properties of solutions?
5. What is the nature of ionization?
6. How does ionization affect the strength of solutions?

Problem 1. What is a solution?

Solvent, solute, and solutions. When we stir salt in water, the little crystals begin to disintegrate and disappear; but the water tastes salty, and we know that the salt must still be present. We call such a mixture a solution of salt and water. The water is called the *solvent* and the salt the *solute.* To understand fully the use of these terms, remember that the dissolving liquid is called the solvent, and the dissolved substance is called the solute. What is a good solvent for sugar? for lard?

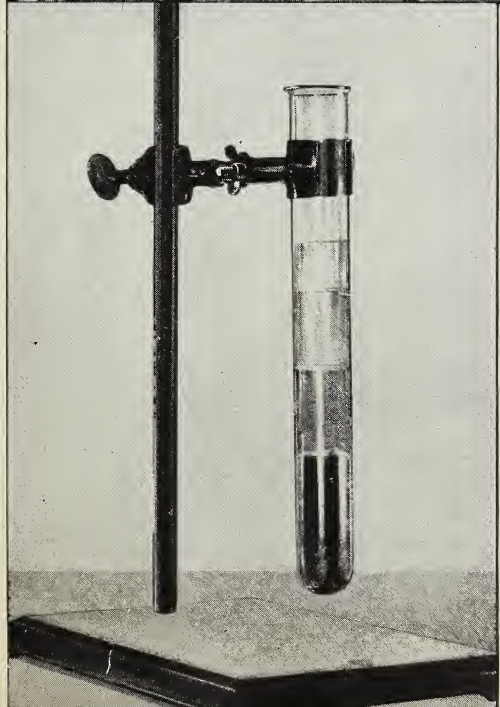
Water is the most common solvent, but there are better solvents for certain things. If you get chewing gum on your clothes or on the carpet at home, it is impossible to remove it with water. Carbon tetrachloride, however, will readily dissolve it. Paraffin will dissolve in gasoline or benzine, rubber in gasoline, and iodine in alcohol. Solutions containing alcohol are often called tinctures or spirits.

When a crystal of salt dissolves in water, it disintegrates, and the little molecules scatter throughout the solution and, being very small, cannot be seen. A true solution is one in which all the solute has separated into molecules that are scattered evenly throughout the solvent.

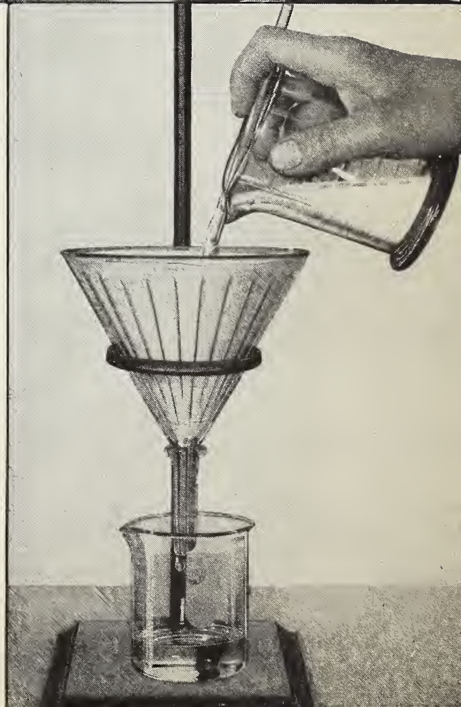
If you should take a glass of muddy water from a river and allow it to settle, the water would become clear. The small suspended particles fall to the bottom. These small particles were held in suspension in the water and were not really in solution. The solute in a true solution will not settle out.

The separation of solids from liquids. How could you get salt which has been dissolved in water into the dry, crystal state again? If there is any dissolved mineral matter in water, it will not settle out but will remain in solution. However, dissolved mineral matter may be removed from water by the process of *distillation.* In this process the water solution is boiled and the water completely vaporized, so that the dissolved minerals are left in the containing vessel. By condensing the water vapor, pure water may be obtained. The apparatus shown

Ford Motor Company



Above, a chemist is making a separation by distillation. At the right, a solid is being separated from a liquid by filtration. At the left are shown immiscible liquids —liquids which do not mix



on the preceding page is used in the laboratory for distillation purposes.

Suspended matter may be removed from water by several means. In the laboratory, insoluble suspended matter may be removed by allowing it to settle and then carefully pouring off the clear liquid. This process is called *decantation.* A more rapid method frequently used is *filtration.* This is effected by pouring the liquid containing the suspended matter through a porous substance, such as paper or asbestos fiber, which allows the liquid to pass through but retains the solid material.

Cities often filter muddy river water for domestic purposes by allowing it to run through sand, gravel, and charcoal, thus ridding it of suspended impurities. You will learn more about this when you study the chemistry of water purification.

Sometimes suspended particles are so small that they are hard to separate from the liquids and will not settle out. Such mixtures appear to be true solutions, but in reality they are suspensions because the particles have not broken down into individual molecules. Such small particles are called colloids. Milk and blood are good examples of colloidal solutions.

Other kinds of solutions. In addition to a solution of a solid in a liquid, there are several other kinds of solutions. You probably know that one liquid may be dissolved in another. For example, alcohol or glycerin is often dissolved in water and used as an antifreeze in automobile radiators. It is also possible for one solid to be dissolved in another. Thus, if molten copper and zinc are mixed together, they form a solution which, when solidified, is called brass. Such a solid solution is an alloy. Other solutions are those of a gas dissolved in a gas and a gas dissolved in a liquid. Can you give examples of the last two solutions?

EXERCISES

1. What is a solvent? a solute? Give examples.
2. What is the most commonly used solvent?
3. Name several commonly used solvents.
4. What is a true solution?
5. Describe the following methods of separating solids from liquids: (*a*) filtration, (*b*) decantation, and (*c*) distillation.
6. What are colloidal solutions?

Problem 2. How may the speed of solution be increased?

How can we make things dissolve faster? If you pour some crystals of rock sugar into a glass of water, they go into solution slowly. We can speed up the action by doing any one of several things. Can you suggest some of them? *Stirring* the solution brings the crystals into better contact with the water and scatters the molecules more rapidly. *Grinding* the crystals into a fine powder causes them to go into solution more rapidly because the powdering greatly increases the surface of the sugar particles. *Heating* also increases the speed with which a solid goes into solution. This is true because the heat increases the speed with which the molecules bombard one another.

EXERCISES

1. Name three methods of increasing the speed of solution.
2. Tell why the three methods named in Problem 2 cause substances to dissolve faster.

Problem 3. What are the kinds of solutions?

Dilute, concentrated, saturated, and supersaturated solutions. If we dissolve but few crystals of sugar in water, we say the solution is dilute; and as we dissolve more sugar, we increase the concentration. A solution containing a low percentage of a solute is said to be *dilute*, while one which contains a high percentage is *concentrated.* It is evident from these definitions that the degree of dilution and concentration can vary between wide limits. You have no doubt observed that there is a limit to the amount of sugar which can be dissolved in iced tea. If you put more sugar in, it settles to the bottom, regardless of how much you stir the solution. Such a solution is said to be saturated with sugar. When a solution contains all a dissolved solute that it can hold under ordinary conditions at a specific temperature, it is said to be *saturated.* If we should heat the iced tea, a little more of the sugar would go into the solution. The capacity of a solvent for a solute usually increases with the temperature. It is possible to take a warm saturated solution and, by carefully cooling it, cause it to retain the solute in solution, though it is holding more than it should hold at the lower temperature. Such a solution is *supersaturated* and is very unstable. By stirring it or by dropping a small crystal of the solute into it or by continued evaporation or cooling, the excess solute crystallizes out. These factors sometimes cause honey or sirup to "turn to sugar"; that is, the sugar is crystallized, or deposited from the solution.

Supersaturation and candymaking. In making fudge, some of the water is boiled off as steam. If a thermometer is placed in the candy solution, the temperature will be shown to increase as the water is removed. The rise in temperature is due to the fact that the more of a solid solute there is in a given amount of solvent, the higher the boiling point of the solution. As cooking continues, the temperature of the fudge rises because the increased evaporation of water causes an increase in the concentration of the solution, which, in turn, raises the boiling point. When a certain temperature or saturation point is reached, the candy is done and should be removed from the stove. If you use a thermometer, as all candy-manufacturers do, you will know when to stop heating the candy. You do not have to depend upon the unreliable method of cooking the candy until a soft ball forms in cold water or until it strings in the air. But this is not the only point where care should be used in making candy. If you have made candy at home, such as fudge or fondant, you have found that sometimes large crystals form, causing a coarse-textured candy when you wished the candy to be of fine texture. This may be the result of boiling off too much water, which causes the resulting supersaturated solution to crystallize when cool. The texture of the candy may also be controlled by stirring and by being sure that no outside crystals of sugar get into the cooling mass. The large crystals would act in such a way as to cause the formation of many more of the same size.

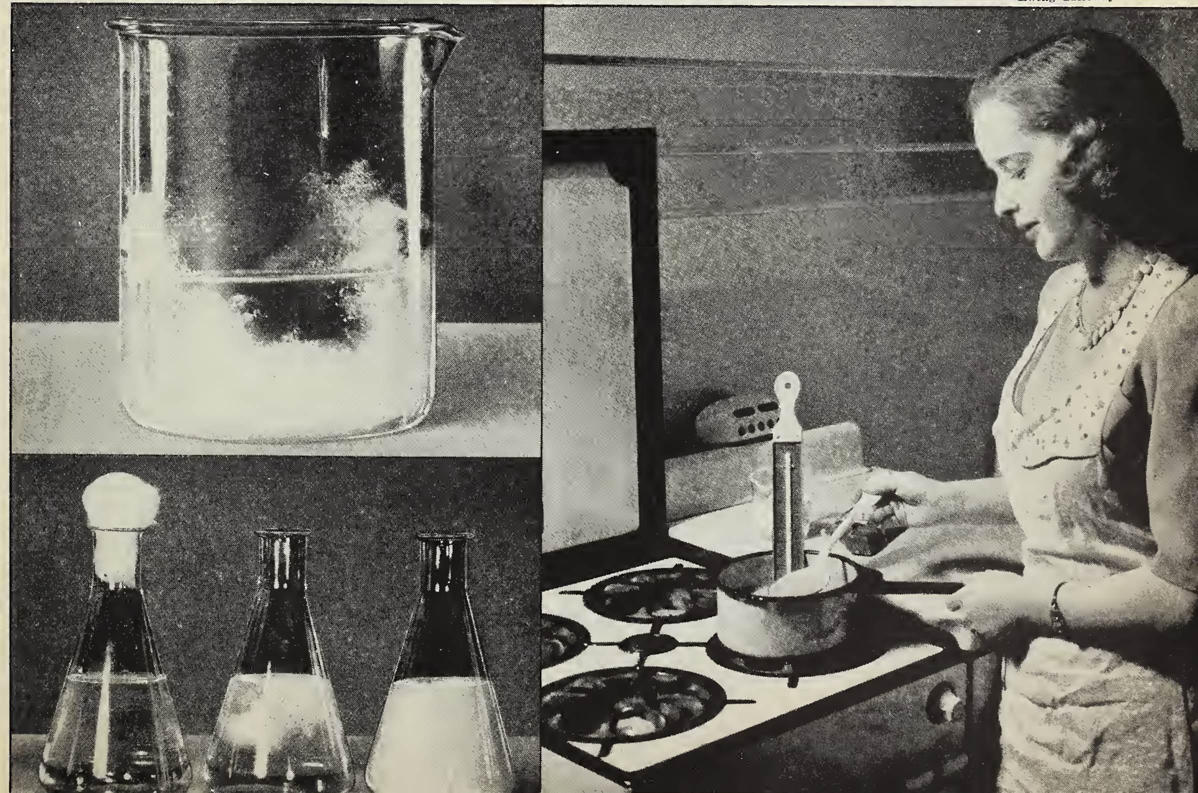
EXERCISES

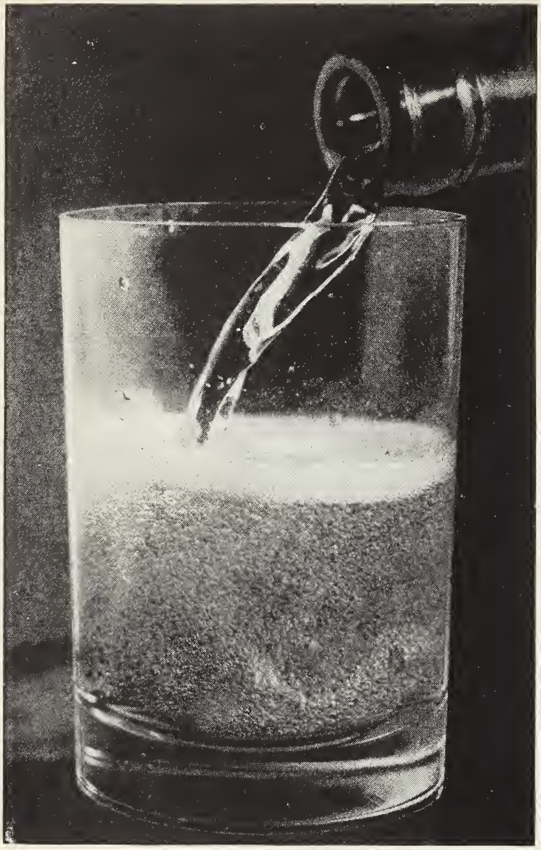
1. What is the difference between a dilute and a concentrated solution? Give examples.

2. What is a saturated solution? How may such a solution be made?

The stoppered flask in the lower picture contains a supersaturated solution of sodium thiosulfate. Can you explain what has happened in the other two flasks? The crystallization of sugar in the making of candy may be avoided by the use of the candy thermometer. Why?

Ewing Galloway





Technology Review

Why do bubbles of carbon dioxide rise to the top of a carbonated beverage after it has been poured from the bottle? How can the effervescence be decreased?

3. What is a supersaturated solution? How is it made?
4. What causes jelly sometimes to "turn to sugar"?
5. How may a thermometer be used in making candy?

Problem 4. What factors affect the properties of solutions?

Solutes affect the boiling point and freezing point of solutions. It has been pointed out that the presence of a solute in water will raise its boiling point. In addition, the presence of a solute will lower the freezing point of water. If salt is added to water, the freezing point is lowered. The more of a solute that is added to a given amount of water, the lower the freezing point will be. Brine, a salt solution, is used to make ice in cold-storage plants because the brine has a lower freezing point than water. Rock salt is sometimes placed on sidewalks, where it dissolves in the water and keeps ice from forming. If you go on a visit in the winter and your house is not to be heated, there may be danger that the pipes will burst from the freezing of the water. Water, as you know, freezes at 32° F and expands upon freezing. To prevent this, the water is turned off, and all the water drained from the entire water system of the house, such as the water-heater, radiators, and toilet-flushing reservoir. These are usually easy to drain, but there remains water in the U turns under sinks and toilets. It is often hard to remove this water. To prevent water from freezing in these traps, salt may be poured into them. The salty solution will not freeze at ordinary winter temperatures.

Pressure and heat affect the solubility of gases. When you open a bottle of soda pop, small bubbles of a gas begin to appear. This gas has been dissolved in water under pressure and is released when the pressure is reduced by removing the cap. Gases, then, will dissolve in certain liquids. There are several factors which affect the solubility of a gas in a liquid. We have said that a gas (carbon dioxide) is dissolved in soda pop under pressure. By increasing the pressure of a gas over a liquid, we increase the solubility of the gas in the liquid. You have perhaps noticed that warm soda water *effervesces* (bubbles) more rapidly than cold soda water. Gases are more soluble in cold liquids than in warm ones. How could you remove dissolved air from water?

EXERCISES

1. What effect does a solute have upon the boiling and freezing points of water?
2. What practical use is made of the change in the freezing point of water when a solute is dissolved in it?
3. How may large quantities of a gas be dissolved in water?
4. What effect does heat have upon the solubility of a gas in water?

Problem 5. What is the nature of ionization?

Why was the theory of ionization proposed? There are several phenomena connected with solutions that scientists were unable to explain for a long time. For example, it was noticed that a solution of sugar in water would not conduct an electric current, while a solution of salt in water would conduct a current very well. It was also noticed that solutions containing equal numbers of molecules of different substances did not always freeze at the same temperature. Moreover, it was observed that solutions of different compounds sometimes had a common property. Copper sulfate, copper chloride, and copper acetate solutions are all blue in color.

No explanation was proposed for these seemingly unrelated phenomena until the Swedish chemist Arrhenius began his studies of solutions in 1883. Arrhenius finally proposed the theory of ionization, which most nearly explains what takes place in solutions. He advanced the theory that when some substances are dissolved in a solvent, not only do they disintegrate into molecules, but the molecules themselves break into ions, which may move about independently of one another. Thus, when salt ($NaCl$) is dissolved in water, the Na^+ ion and the Cl^- ion separate as follows:

$$NaCl \longrightarrow Na^+ + Cl^-$$

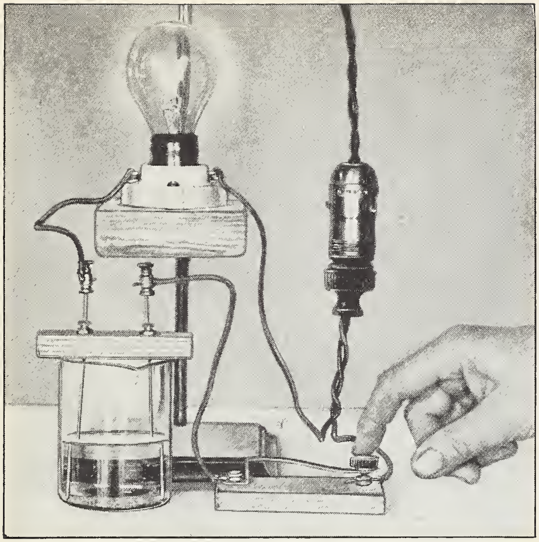
When they separate, the Na part of the molecule has a positive charge, since it has given an electron to the Cl atom. The Cl part of the molecule then has a negative charge. We must not confuse the dissociation of ionizing substances in solution with the decomposition of chemical compounds. When substances ionize in solution, the breaking apart of the molecules is a temporary condition which exists as long as there is enough of the solvent. If all the solvent is evaporated off, the solute will no longer be ionized.

Electrolytes and nonelectrolytes. Many substances when dissolved in water become conductors of an electric current and are known as *electrolytes.* This property of an electrolyte is due to the formation of ions which are capable of conducting an electric current because the ionic particles bear charges of electricity. For this reason, a solution of salt in water will conduct an electric current.

When sugar or most other organic compounds are put into solution, they separate into molecules; but there the disintegration stops, and no ions are formed. Solutions of compounds which do not ionize do not possess electrically charged particles and will not conduct an electric current. Such substances are called *nonelectrolytes.*

Svante August Arrhenius (1859–1927), the Swedish chemist, is noted for his discovery of the theory of ionization and for his work in the fields of astronomy and medicine

Further proof that ionization takes place. If we dissolve 1 gram-molecular weight of sugar in 100 cubic centimeters of water, the freezing point of the water is lowered a definite number of degrees because the presence of a solute in a solvent lowers the freezing point of the solvent. If we dissolve 1 gram-molecular weight of $NaCl$ in 100 cubic centimeters of water, the number of molecules in the solution will be the same as those in a 100-cubic-centimeter water solution of a gram-molecular weight of sugar. However, the freezing point of the salt solution will be lowered approximately twice that of the sugar solution. This is not a peculiar property of $NaCl$, since 1 gram-molecular weight of KNO_3, NH_4Cl, or HCl, dissolved in 100 cubic centimeters of H_2O, would lower the freezing point the same amount. $CaCl_2$, however, lowers the freezing point approximately three times as much as sugar, while aluminum sulfate ($Al_2(SO_4)_3$) lowers the freezing point approximately five times as much as sugar. Arrhenius decided that the reason for this difference lay in the fact that when certain substances were dissolved, the molecules separated into small electrically charged particles called ions.



This apparatus is used to test the conductivity of a solution. When a nonelectrolyte, such as sugar, is dissolved in the water in the beaker, the electric current is not conducted between the two wires in the solution, and consequently the light bulb in the circuit will not burn. When an electrolyte, such as sodium chloride, is dissolved in water, it breaks up into ions, which conduct the current between the wires, causing the lamp in the circuit to glow. The conductivity of the solution, or the degree of ionization, is proportional to the brightness of the lamp

When sugar ($C_{12}H_{22}O_{11}$) was dissolved in water, he reasoned that the molecules did not ionize, or separate, and there still remained the same number of particles dissolved in the water. When NaCl was dissolved, it divided, or dissociated, into Na^+ ions and Cl^- ions, which made twice as many particles in the water and thereby caused a lower freezing point. A molecule of $Al_2(SO_4)_3$ breaks up into two aluminum ions and three sulfate ions, making five times as many particles in the solution. The freezing point of a solution depends not upon the kind of particles in the solution, but upon the number.

Further proof that ionization occurs may be found in the fact that certain ions retain characteristic properties, regardless of the other ions with which they are combined. For example, copper solutions usually all show the characteristic blue color of the copper ion. There are a number of other reasons why we believe the theory of ionization to be true, but we will not discuss them in this study.

EXERCISES

1. What is ionization?
2. Write an equation showing how potassium chloride ionizes.
3. Why do ions have a positive or a negative charge?
4. What is an electrolyte? a nonelectrolyte? Give examples.
5. How can you prove that ionization takes place?

Problem 6. How does ionization affect the strength of solutions?

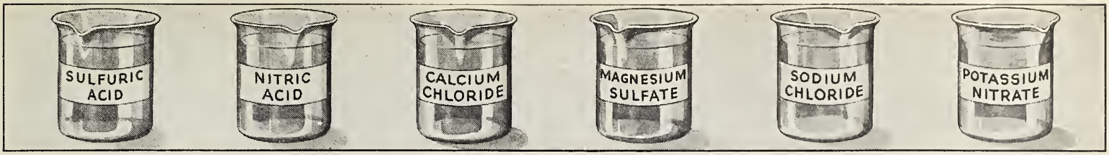
Dilution increases ionization. Though the molecules of an electrolyte ionize when they are in solution, there is never 100 per cent ionization. If we dissolve a spoonful of salt in a glass of water, not all the molecules break up into ions. If more water is added, more salt molecules break up into ions. Dilution increases ionization.

The degree of ionization determines the strength of solutions. Substances which ionize highly are said to be strong. Hydrochloric acid is a strong acid because it ionizes highly in dilute solution. We should be careful not to confuse the terms *concentrated* and *dilute* with the terms *strong* and *weak*. If there is very little water in acetic acid, we say that it is concentrated. Adding water dilutes the acid. Since acetic acid does not ionize very much even in dilute solutions, it is said to be weak. Strength, then, depends upon the ability of a compound to ionize in solution. Technically you are wrong when you say that your coffee is too strong and you wish to add some water to weaken it. You really should say, "Please put some water in my coffee to dilute it, since it is too concentrated."

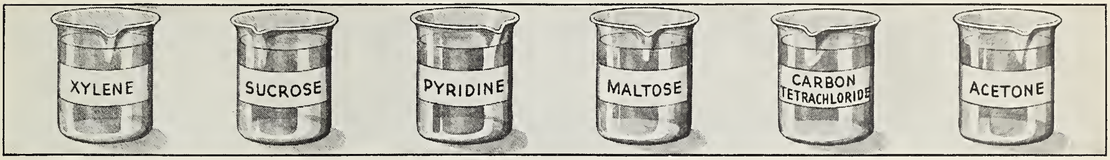
You can put vinegar, which is essentially dilute acetic acid, in foods because it does not ionize highly. It would not be safe to put hydrochloric acid in foods to make them sour because it ionizes fifty times as much as acetic acid. Boric acid may be used in the eyes because it is a very weak acid.

EXERCISES

1. What determines the percentage of ionization of an electrolyte in a solution?
2. What determines the strength of a solution?
3. Distinguish between the terms *strong*, *weak*, *concentrated*, and *dilute* as applied to solutions.



Some common electrolytes (above) and nonelectrolytes (below)



UNIT EXERCISES

Some of these statements are true, while others are false. On a separate piece of paper indicate which are true and which are false.

1. Water is a good solute for sugar.

2. Carbon tetrachloride will dissolve chewing gum.

3. Water is the most common solvent in the world.

4. Gasoline is often used as a solvent.

5. Decantation is the process of running a mixture through a sieve.

6. True solutions are made up of colloids.

7. Increasing the temperature of a mixture of sugar and water will increase the speed with which it forms a solution.

8. A saturated solution is more dilute than a supersaturated solution.

9. The more of a solute that there is in a given amount of a solvent, the higher the boiling point of the solution.

10. The more of a solute that there is in a given amount of a solvent, the lower the freezing point of the solution.

11. All solutes are solids.

12. When sugar crystallizes out of water or honey, it is said to effervesce.

13. Joseph Priestley was the first chemist to offer a true explanation of the phenomenon called ionization.

14. Electrolytes in solution will conduct an electric current.

15. An ion is a wandering part of a molecule which carries an electrical charge.

16. Sugar is an electrolyte.

17. If the same number of molecules of an electrolyte and a nonelectrolyte are dissolved in equal amounts of water, the freezing point will be lowered to the same extent.

18. Solutions of copper sulfate and copper nitrate are each blue in color because of the ionization of copper.

19. A sodium ion is always negatively charged.

20. A damp piece of cloth is a poor insulator because of the ionization of mineral substances in the water.

21. When a substance is ionized, its molecules are broken into smaller particles.

22. The ions in a solution neutralize one another when the water is evaporated.

23. Acetic acid is a strong acid.

24. A weak acid is a dilute acid.

25. A highly concentrated solution is always a well-ionized solution.

26. Dilute hydrochloric acid is known as a strong acid because it ionizes highly.

27. Boric acid is a weak acid because its solution is one in which relatively few molecules are broken apart.

28. Ions and atoms have the same properties.

29. Metallic ions are positively charged, and nonmetallic ions are negatively charged.

30. This ionic equation shows how hydrochloric acid ionizes in dilute solution:

$$HCl \longrightarrow H^+ + Cl^-$$

REFERENCES FOR FURTHER READING

Clarke, Beverly L. *Marvels of Modern Chemistry.* Harper & Brothers, New York, 1932.

Foster, William. *The Romance of Chemistry.* D. Appleton-Century Company, Inc., New York, 1936.

UNIT 9

Chemical Equations

We have seen how the chemist expresses the formula of a chemical compound by the use of the symbols of elements. Though formulas tell the chemist many things which he wishes to know, he is also interested in the making and the using of chemical compounds. In the laboratory, in industry, and in everyday life, compounds usually undergo chemical changes. These changes are best expressed by what the chemist calls chemical equations. The use of these equations helps to make chemistry an exact science. It is impossible to understand chemical reactions without equations. In all chemical reactions the amounts of the reacting materials and amounts of the products which are formed are definite and fixed. We may have present more than enough of one of the substances, but only the amount which is needed to make the reaction complete will be used.

As an example of a common chemical reaction let us take the burning of natural gas. The chief constituent of this material is methane, which has the formula CH_4. Chemical analysis and experimentation prove that when this gas burns, the products formed are water and carbon dioxide. We may quantitatively express what happens as follows:

$$\begin{array}{ccccccc} \text{methane} & + & \text{oxygen} & \longrightarrow & \text{water} & + & \text{carbon dioxide} \\ CH_4 & + & 2\,O_2 & \longrightarrow & 2\,H_2O & + & CO_2\uparrow \end{array}$$

This is a short, concise, and definite way to tell what happens. It also enables one who understands equation-writing to tell exactly how much methane and oxygen are used and exactly how much water and carbon dioxide will be produced. These facts are also true for all the countless chemical reactions which take place around us. Therefore, for the sake of economy of time, efficiency, and complete understanding, the use of chemical equations is necessary. You will be unable to comprehend the practical chemistry which follows this part of your book unless you master equation-writing.

PURPOSES TO BE ACHIEVED

1. To master the methods of equation-writing.
2. To learn how to interpret chemical equations.
3. To develop a more complete understanding of chemistry.

PROBLEMS TO BE SOLVED

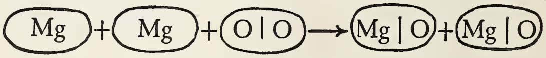
1. What is a balanced chemical equation?
2. How can we predict what chemical changes will take place?
3. How do we write balanced chemical equations?
4. How can the principles of oxidation and reduction be used in writing balanced equations?
5. How can the weights of the chemicals used and produced in a chemical reaction be determined?
6. How may the volumes of the gases used and produced in a chemical reaction be determined?

Problem 1. What is a balanced chemical equation?

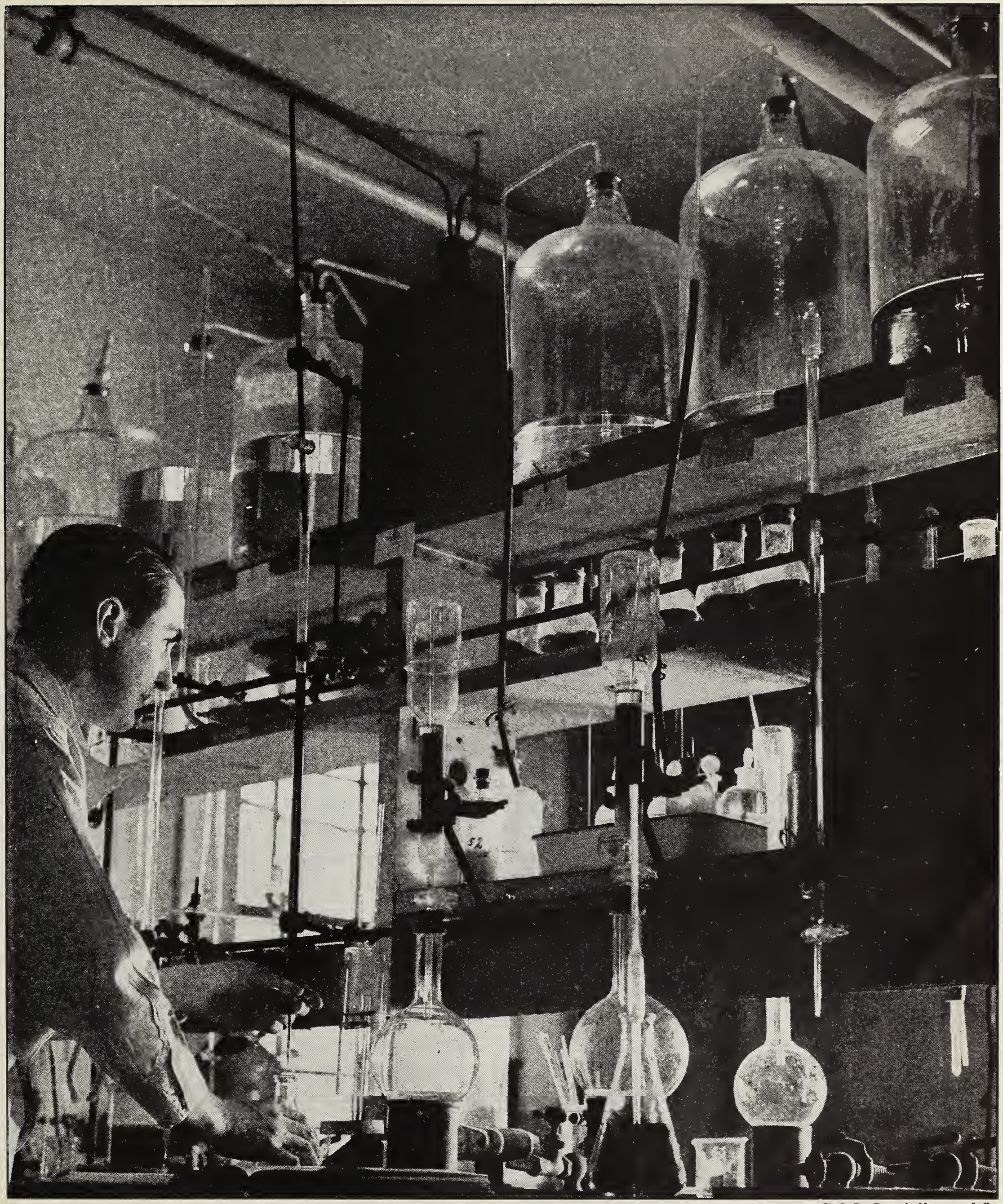
True equations must be balanced. You will recall that one of the fundamental laws of nature is that man can neither make nor destroy matter. This means that in every chemical reaction the number of atoms remains the same. There is only a rearrangement of the atoms to form new compounds. Thus, in the reactions which take place when magnesium burns in oxygen, let us see what happens to the atoms of the reacting materials:

$$\begin{array}{ccccc} \text{magnesium} & + \text{ oxygen} & \longrightarrow & \text{magnesium oxide} \\ 2\,Mg & + \; O_2 & \longrightarrow & 2\,MgO \end{array}$$

If we let each atom or molecule be represented by a circle with its symbol inside, we have



Notice that we have two atoms of magnesium and one molecule of oxygen (consisting of two atoms) on the left side of the equation, and on the right side two molecules of magnesium oxide, each consisting of one atom of magnesium and one atom



E. I. Du Pont de Nemours & Co.

Chemistry is an exact science. This research chemist must measure with extreme accuracy the materials that he uses of oxygen. Thus the number of atoms of magnesium and oxygen is the same on one side of the equation as on the other. The number of atoms which is on one side of the equation is exactly equal to the number which is on the other side. Such an equation is said to be *balanced.* A chemical equation is not a true equation unless it is balanced. Check the number of each kind of atoms on each side of the equation which shows the burning of methane to make sure that it is balanced.

EXERCISES

1. Why is it impossible for atoms to be destroyed in a chemical reaction?

2. When is an equation said to be balanced?

Problem 2. How can we predict what chemical changes will take place?

Equations help us to predict chemical changes. It is often possible to predict accurately what will happen in a chemical reaction, that is, what products will be formed, the amounts of these products, and other important factors. However, to be able to do this requires a complete understanding of all kinds of chemical reactions. To help you to get this understanding, we will classify the many hundreds of reactions into definite types.

There is one precaution you must observe in your thinking about equations of chemical reactions. It is this: an equation is a short method of writing what *did* happen in a reaction; it is not an infallible indication of what *will* happen. Thousands of chemical reactions have been studied and the products analyzed. For each reaction a true chemical equation has been written. The knowledge of equations is very useful in our study of chemical reactions, but a chemist always checks by analysis the products formed before he writes the equation for a reaction.

It is impossible for anyone to memorize all the equations for the chemical reactions which have been determined. Therefore these reactions have been classified into several different types. In your study of equations it is first necessary that you recognize the type of reaction for which you expect to write the equation. Then, if you have mastered the technique used in writing each type, you will be able to write any equation with reasonable assurance of its correctness. There is an equation for every chemical reaction.

Types of chemical reactions. The following types of chemical reactions will be explained and discussed in this unit:

Type I. Simple union, or direct combination, of elements.

Type II. Displacement of one element in a compound by another which is more active.

Type III. Metathesis, or double displacement.

Type IV. Decomposition of a compound due to some outside influence, such as heat, light, or electricity.

EXERCISES

1. Why is it essential for you to have an understanding of the several types of reactions?

2. What precautions should be observed in predicting from an equation what chemical changes will take place?

Problem 3. How do we write balanced chemical equations?

Type I. Simple union, or direct combination, of elements. As the name implies, this type of reaction represents the union of two elements to form a compound. One of the elements may be a metal and one a nonmetal, or both may be nonmetals. If you will refer again to the activity table on page 66, you can anticipate, to a certain degree, the relative activity of each metal. Those metals high in the series are very active and combine with most nonmetals very readily. The lower the position of a metal in this series, the less active it is. Therefore gold and platinum combine with very few nonmetals.

In order that you may become familiar with writing this type of equation, let us consider the various steps involved when aluminum combines with oxygen. When one element unites directly with another element, the name of the resulting compound ends in *ide*; consequently the product of this reaction is named aluminum oxide. We may write the word equation for this reaction as follows:

$$\text{Aluminum} + \text{oxygen} \longrightarrow \text{aluminum oxide}$$

Now let us consider how to write the formula equation. Metals have only one atom in each molecule; therefore aluminum is written Al. The oxygen, which contains two atoms per molecule, is written O_2.

Our first step in writing the equation, then, is to write the *correct formula for one molecule* of each of the reacting substances:

$$Al + O_2 \longrightarrow$$

The second step is to write the correct formula for one molecule of the product which is formed:

$$Al + O_2 \longrightarrow Al_2O_3$$

The third step is that of balancing the equation; that is, we must show quantitatively how many atoms enter into the reaction and how many are in the product. An accounting must be made of every atom, or, in other words, the equation must be *balanced.*

There are two ways of balancing this type of equation. The first is the least-common-multiple method. Where this method is used, the equation is first written as follows:

$$\overset{3}{Al} + \overset{4}{O_2} \xrightarrow{12} \overset{6}{Al_2}\overset{6}{O_3}$$

Since the aluminum atom must give three electrons to the oxygen atom, it has a valence of 3, and so we place this number above the aluminum atom. Each atom of oxygen can gain only two electrons; but since there are two atoms in a molecule of oxygen, the molecule will receive four electrons. We, therefore, write a small 4 above the oxygen. In the product Al_2O_3 there are two atoms of Al, each with a valence of 3 +, which makes a total valence of 6. Place this figure above the Al. In like manner, the three atoms of oxygen will have a total valence of 6. We next determine the L.C.M. of these numbers. The L.C.M. of 3, 4, 6, and 6 is *12.* This figure is placed above the arrow.

Now divide the number which represents the *total* valence of each atom into the L.C.M., and we obtain the total number of molecules of each substance required to balance the equation. Place the number obtained before each molecule, thus:

$$4\,Al + 3\,O_2 \longrightarrow 2\,Al_2O_3$$

The fourth and final step is perhaps the most important. Check the entire equation to see if the number of atoms on the left-hand side equals the number of atoms on the right-hand side. Checking, we find four atoms of Al and six atoms of oxygen on each side of the equation.

Remember that after you have written the correct formula for each of the combining substances and each of the products formed, you must not make any changes except in the figure in front of each molecule. In other words, there is only one correct formula for a substance, but you can change the number of molecules in order to balance the equation.

Another method of balancing an equation which is often used is the accounting method. If we wish to balance the equation for the reaction between aluminum and oxygen by this method, we proceed as follows:

First, write the correct formula for one molecule of each of the reacting substances and the product formed, as in the L.C.M. method:

$$Al + O_2 \longrightarrow Al_2O_3$$

The reaction which takes place in the photoflash bulb when this boy takes a picture is an example of the direct union of two elements. What are the elements?

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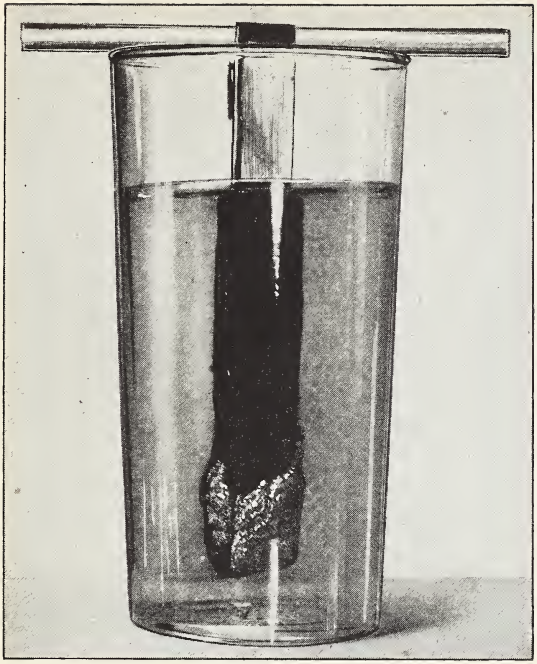


When a strip of copper is suspended in a solution of silver nitrate, the silver is displaced from the solution by the more active copper. The solution will gradually turn blue as copper nitrate is formed. What type of chemical reaction is this? Can you write the equation for the reaction?

Now, since there must be the same number of atoms of each element on each side of the equation, we first look at the Al. There are two Al atoms on the right-hand side of the equation and only one on the left; so we tentatively write a 2 in front of the left-hand Al:

$$2\ Al + O_2 \longrightarrow Al_2O_3$$

There are two oxygen atoms on the left and three on the right.

The L.C.M. of 2 and 3 is 6; so we must place a 3 in front of the O_2 and a 2 in front of the Al_2O_3:

$$2\ Al + 3\ O_2 \longrightarrow 2\ Al_2O_3$$

When we check our equation, we find that we now have four Al atoms on the right and must, therefore, change the 2 which we tentatively placed in front of the left-hand Al to 4. Checking again, we see that the equation is balanced:

$$4\ Al + 3\ O_2 \longrightarrow 2\ Al_2O_3$$

In your work, you may use either the L.C.M. method or the accounting method.

Let us try another example. When phosphorus unites with chlorine, phosphoric chloride is formed, and the word equation for the reaction may be written thus:

Phosphorus + chlorine ⟶ phosphoric chloride

To write the formula equation, first write the correct formula for one molecule of each of the reacting substances:

$$P + Cl_2 \longrightarrow$$

Second, write the correct formula for the product formed:

$$P + Cl_2 \longrightarrow PCl_5$$

Third, place above each atom its *total* valence and find the L.C.M.:

$$\overset{5}{P} + \overset{2}{Cl_2} \xrightarrow{10} \overset{5\ 5}{PCl_5}$$

Fourth, divide the total valences into the L.C.M. and place the quotient in front of each molecule:

$$2\ P + 5\ Cl_2 \longrightarrow 2\ PCl_5$$

Fifth, check: there are two phosphorus atoms on each side and ten atoms of chlorine on each side; therefore the equation is balanced. You may try the accounting method on this reaction if you wish.

EXERCISES

Balance the following equations.

Write the word equation and the formula equation for each reaction.

1. Antimony + chlorine ⟶
2. Aluminum + sulfur ⟶ (Sulfur has only one atom in each molecule.)
3. Phosphorus + iodine ⟶
4. Sodium + oxygen ⟶ sodium oxide
5. Magnesium + iodine ⟶
6. Chromium + bromine ⟶
7. Carbon + oxygen ⟶ carbon dioxide
8. Sulfur + oxygen ⟶ sulfur dioxide
9. Hydrogen + oxygen ⟶
10. Silver + bromine ⟶
11. Copper + chlorine ⟶ cupric chloride
12. Arsenic + oxygen ⟶ arsenic oxide
13. Silver + sulfur ⟶
14. Lead + oxygen ⟶ lead monoxide

Type II. Displacement of one element in a compound by another which is more active. 1. *Displacement of metals in metallic compounds by metals.* Metals high in the displacement series (see page 66), being more active, will displace metals lower in the series from a solution of their compounds.

When a strip of aluminum metal is placed in a solution of a silver sulfate, the aluminum displaces the silver from the solution because it is a more active metal. In writing and balancing the equation for this reaction, we may use the same method which was employed in writing simple-union equations. Illustrating this method, we begin by writing the true formulas for the reacting substances and the products formed:

$$Al + Ag_2SO_4 \longrightarrow Al_2(SO_4)_3 + Ag$$

Next place above each metallic atom or ion its total valence:

$$\overset{3+}{Al} + \overset{2+}{Ag_2SO_4} \longrightarrow \overset{6+}{Al_2(SO_4)_3} + \overset{1+}{Ag}$$

Then find the L.C.M. of these numbers and place it above the arrow:

$$\overset{3+}{Al} + \overset{2+}{Ag_2SO_4} \overset{6}{\longrightarrow} \overset{6+}{Al_2(SO_4)_3} + \overset{1+}{Ag}$$

Finally we divide each total valence into the L.C.M. *6* to obtain the number of molecules for each of the products:

$$2\,Al + 3\,Ag_2SO_4 \longrightarrow Al_2(SO_4)_3 + 6\,Ag$$

Checking, we find that there are two atoms of aluminum, six atoms of silver, and three sulfate ions on each side of the equation. Therefore the equation is *balanced.*

At this point, it is necessary that you write the word equation in order that you may associate the correct name of a compound with its formula:

$$\begin{array}{lllll} \text{Aluminum} + & \text{silver sulfate} & \longrightarrow & \text{aluminum sulfate} + & \text{silver} \\ 2\,Al + & 3\,Ag_2SO_4 & \longrightarrow & Al_2(SO_4)_3 + & 6\,Ag \end{array}$$

2. *Displacement of hydrogen in acids by active metals.* While the physical properties of hydrogen do not indicate that it is a metal, chemically it has metallic properties. It has a valence of 1 + and is displaced by metals above it in the displacement series from some of its compounds. Metals above hydrogen in the displacement series will displace it from most acids. For example, when zinc is placed in hydrochloric acid, the zinc replaces the hydrogen, and the equation may be written in the following steps:

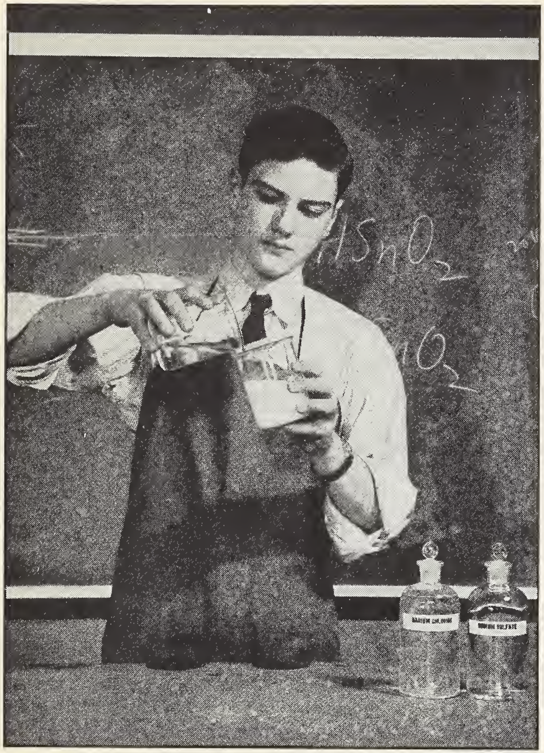
1. $HCl + Zn \longrightarrow ZnCl_2 + H_2$
2. $\overset{1+}{HCl} + \overset{2+}{Zn} \longrightarrow \overset{2+}{ZnCl_2} + \overset{2+}{H_2}$
3. $\overset{1+}{HCl} + \overset{2+}{Zn} \overset{2}{\longrightarrow} \overset{2+}{ZnCl_2} + \overset{2+}{H_2}$
4. $2\,HCl + Zn \longrightarrow ZnCl_2 + H_2$
5. Hydrochloric acid + zinc
   → zinc chloride + hydrogen

This type of equation is very easily balanced by the accounting method.

3. *The displacement of hydrogen in water by metals.* The active metals Na, K, and Ca will displace one half of the hydrogen of water and form hydroxides of the metals. In writing this type of equation, the displacement becomes apparent if the formula for water is written HOH instead of H_2O. For example, when sodium is placed in water, the sodium displaces one half of the hydrogen of the molecule of HOH. The steps in writing the equation are

1. $HOH + Na \longrightarrow NaOH + H_2$
2. $\overset{1+}{HOH} + \overset{1+}{Na} \longrightarrow \overset{1+}{NaOH} + \overset{2+}{H_2}$
3. $\overset{1+}{HOH} + \overset{1+}{Na} \overset{2}{\longrightarrow} \overset{1+}{NaOH} + \overset{2+}{H_2}$
4. $2\,HOH + 2\,Na \longrightarrow 2\,NaOH + H_2$
5. Water + sodium
   → sodium hydroxide + hydrogen

4. *Displacement of halogens.* The four nonmetals F_2, Cl_2, Br_2, and I_2 have similar properties and are called the halogen family. Their activity decreases in the order named. A more active halogen will displace one which is less active from a solution of its compound. For example, chlorine will displace the less active bromine from ferric bromide. We may balance this equation by the L.C.M. method if we place the total charge, or valence, above the negative ions rather than the positive ions. We may do this because the total negative valence always equals the total positive valence of the molecule of any compound.



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When a solution of potassium sulfate is poured into a solution of barium nitrate, white barium sulfate is precipitated from the solution. This is an example of metathesis, or double-displacement reaction. Can you write the equation for the reaction?

1. $FeBr_3 + Cl_2 \longrightarrow FeCl_3 + Br_2$
2. $Fe\overset{3-}{Br_3} + \overset{2-}{Cl_2} \longrightarrow Fe\overset{3-}{Cl_3} + \overset{2-}{Br_2}$

$$6$$

3. $Fe\overset{3-}{Br_3} + \overset{2-}{Cl_2} \longrightarrow Fe\overset{3-}{Cl_3} + \overset{2-}{Br_2}$
4. $2\,FeBr_3 + 3\,Cl_2 \longrightarrow 2\,FeCl_3 + 3\,Br_2$
5. Ferric bromide + chlorine
   ⟶ferric chloride + bromine

Be sure that you write the halogens with two atoms in the molecule when they are in the free state. When a halogen is combined with some other element in a compound, the number of atoms of the halogen depends upon the valence of the other element. NaCl, CaI_2, and $FeBr_3$ are examples.

EXERCISES

Write the word equation and the balanced formula equation for each of these reactions:

1. Zinc + lead nitrate ⟶
2. Potassium + water ⟶
3. Aluminum + hydrochloric acid ⟶
4. Ferric iodide + bromine ⟶
5. Magnesium + silver nitrate ⟶
6. Zinc + phosphoric acid ⟶
7. Calcium + water ⟶
8. Aluminum + mercuric nitrate ⟶
9. Cadmium + sulfuric acid ⟶
10. Chromium bromide + chlorine ⟶
11. Iron + cupric sulfate ⟶ ferrous sulfate +
12. Iron + sulfuric acid ⟶ ferrous sulfate +
13. $NaI + Cl_2 \longrightarrow$
14. Sodium reacting with water ⟶
15. $Fe + \text{steam} \longrightarrow Fe_3O_4 +$

Type III. Metathesis, or double displacement. When a solution of aluminum chloride is added to a solution of silver sulfate, a white precipitate is formed. Laboratory tests prove that this substance is silver chloride. The reaction can be explained by our knowledge of ionization.

An aluminum chloride molecule ionizes in solution into one $\overset{3+}{Al}$ ion and three $\overset{1-}{Cl}$ ions, while the silver sulfate molecule breaks up into two $\overset{1+}{Ag}$ ions and one $\overset{2-}{SO_4}$ ion. When the two solutions are put together, we have the following ions coming into contact with one another:

$$\overset{3+}{Al} + 3\,\overset{1-}{Cl} + 2\,\overset{1+}{Ag} + \overset{2-}{(SO_4)}$$

Silver chloride is insoluble, so that when a silver ion comes into contact with a chloride ion, a molecule of insoluble silver chloride is formed. Since AgCl is insoluble, it is precipitated from the solution.

The Al ions and SO_4 ions remain in the solution. If we filter the solution and allow the water to evaporate, white crystals of $Al_2(SO_4)_3$ are formed. We may write and balance the equation for this type of reaction by the L.C.M. method. The steps used in writing the equation are as follows:

1. Write the true formulas for the reacting substances:

$$AlCl_3 + Ag_2SO_4$$

2. Write the true formulas for the products formed by *exchanging* the positive ions of the reacting substances:

$$Al\,Cl_3 + Ag_2\,SO_4 \longrightarrow Al_2(SO_4)_3 + AgCl$$

3. Write the total valence above each positive ion:

$$\overset{3+}{Al}Cl_3 + \overset{2+}{Ag_2}SO_4 \longrightarrow \overset{6+}{Al_2}(SO_4)_3 + \overset{1+}{Ag}Cl$$

4. Find the L.C.M. of these numbers and place it above the arrow:

$$\overset{3+}{Al}Cl_3 + \overset{2+}{Ag_2}SO_4 \xrightarrow{6} \overset{6+}{Al_2}(SO_4)_3 + \overset{1+}{Ag}Cl$$

5. Divide the total positive valence of each positive ion into the L.C.M. and place the quotient in front of each molecule:

$$2\,AlCl_3 + 3\,Ag_2SO_4 \longrightarrow Al_2(SO_4)_3 + 6\,AgCl\downarrow$$

6. Checking, we find that there are two aluminum ions, six chloride ions, six silver ions, and three sulfate ions on each side of our equation. Therefore it is balanced.

7. Finally we write the word equation:

Aluminum chloride + silver sulfate
⟶ aluminum sulfate + silver chloride

Sometimes we write the ionic equation for the reaction as follows:

$$2\,\overset{3+}{Al} + 6\,\overset{1-}{Cl} + 6\,\overset{1+}{Ag} + 3\overset{2-}{(SO_4)} \longrightarrow 2\,\overset{3+}{Al} + 3\overset{2-}{(SO_4)} + 6\,AgCl\downarrow$$

Since the AgCl is insoluble, it does not ionize.

Metathesis will take place when two soluble ionizing substances are added together and two or more of the ions unite to form an insoluble substance, a gas, or a nonionizing substance, such as water. The solubility rules are given on page 111.

Notice that in metathesis the two positive ions exchange negative ions. Therefore this type of reaction is often called double displacement or double decomposition. An arrow is usually placed pointing down after the formula if a precipitate is formed, and pointing up if a gas is formed.

EXERCISES

Write the word equation and the balanced formula equation for each of the following reactions:

1. Ferric nitrate + ammonium hydroxide ⟶
2. Silver acetate + potassium chloride ⟶
3. Barium chloride + sodium sulfate ⟶
4. Cobalt phosphate + nitric acid ⟶
5. Zinc sulfate + ammonium sulfide ⟶
6. Lead nitrate + potassium bromide ⟶
7. Ammonium chromate + cupric nitrate ⟶
8. Stannic chloride + sodium arsenate ⟶
9. Antimony chloride + hydrogen sulfide ⟶
10. Mercuric nitrate + sodium iodide ⟶
11. Phosphoric acid + calcium hydroxide ⟶
12. Ammonium hydroxide + sulfuric acid ⟶

Type IV. Decomposition of a compound due to some outside influence, such as heat, light, or electricity. There are several agencies which will aid in the decomposition of a compound into simpler substances. Heat and electricity are the forms of energy usually employed in decomposing chemical compounds. Equations of these types of reactions are usually balanced by the accounting method.

1. *Heat.* Many substances, such as hydroxides, carbonates, chlorates, sulfites, and some of the oxides can be decomposed by heat. However, not every compound can be decomposed by heat.

a. All *metallic hydroxides* decompose, when heated, into metallic oxides and water. Thus, when calcium hydroxide is heated, we have

$$Ca(OH)_2 + heat \longrightarrow CaO + HOH\uparrow$$

This reaction runs to completion as the water is driven off as a gas.

Another hydroxide with which you will work and which is formed in many reactions is ammonium hydroxide (NH_4OH). It is very unstable and upon formation decomposes into ammonia (NH_3) and water (H_2O):

$$NH_4OH \longrightarrow H_2O + NH_3\uparrow$$

An example of the formation of ammonium hydroxide in a reaction is that of the chemical combination of ammonium sulfate and calcium hydroxide:

$$(NH_4)_2\,SO_4 + Ca\,(OH)_2 \longrightarrow CaSO_4\downarrow + 2\,NH_4OH$$

Since the ammonium hydroxide is unstable and decomposes into *ammonia* and water, we must show the final products formed in the reaction. Since there are two molecules of ammonium hydroxide, there must be two molecules of ammonia gas and two molecules of water shown in the completed equation:

$$(NH_4)_2SO_4 + Ca(OH)_2 \longrightarrow CaSO_4\downarrow + 2\,H_2O + 2\,NH_3\uparrow$$

In writing and balancing such an equation, first use the rules for metathesis. Then show the decomposition of the unstable product which is formed.

b. Many *acids* decompose, when heated, into nonmetallic oxides and water. Examples:

sulfuric acid + heat ⟶ water + sulfur trioxide

$$H_2SO_4 + \text{heat} \longrightarrow H_2O + SO_3\uparrow$$

sulfurous acid + heat ⟶ water + sulfur dioxide

$$H_2SO_3 + \text{heat} \longrightarrow H_2O + SO_2\uparrow$$

carbonic acid + heat ⟶ water + carbon dioxide

$$H_2CO_3 + \text{heat} \longrightarrow H_2O + CO_2\uparrow$$

Carbonic acid (H_2CO_3) and sulfurous acid (H_2SO_3) are both very unstable, and when they are formed as products in a chemical reaction, the equation must show their final decomposition. Example:

$$Na_2CO_3 + 2\,HCl \longrightarrow 2\,NaCl + H_2O + CO_2\uparrow$$

c. Compounds containing the *chlorate* radical decompose, when heated, into *chloride* compounds and *oxygen* gas. Example:

$$2\,KClO_3 + \text{heat} \longrightarrow 2\,KCl + 3\,O_2\uparrow$$

d. Metallic *carbonates* decompose, when heated, into *metallic oxides* and *carbon dioxide* gas. Example:

$$CaCO_3 + \text{heat} \longrightarrow CaO + CO_2\uparrow$$

Ammonium carbonate ($(NH_4)_2CO_3$) decomposes, when heated, as follows:

$$(NH_4)_2CO_3 + \text{heat} \longrightarrow 2\,NH_3\uparrow + H_2O + CO_2\uparrow$$

e. Oxides, as a rule, are very stable compounds and are not decomposed by heat. However, there are a few exceptions, which are as follows:

$$2\,HgO + \text{heat} \longrightarrow 2\,Hg + O_2\uparrow$$

$$2\,PbO_2 + \text{heat} \longrightarrow 2\,PbO + O_2\uparrow$$

$$2\,MnO_2 + \text{heat} \longrightarrow 2\,MnO + O_2\uparrow \text{ (must be heated strongly)}$$

$$2\,Pb_3O_4 + \text{heat} \longrightarrow 6\,PbO + O_2\uparrow$$

2. *Decomposition by electricity. Electrolysis.* In electrolytic decomposition an electric current is passed through a solution of the compound. The cations (positive ions) migrate to the cathode (negative electrode), and the anions (negative ions) migrate to the anode (positive electrode). The following equations show the reactions of compounds which are commonly decomposed by electrolysis:

$$2\,H_2O + \text{electricity} \longrightarrow 2\,H_2 + O_2\uparrow$$

$$\text{Molten } 2\,NaCl + \text{electricity} \longrightarrow 2\,Na + Cl_2\uparrow$$

$$2\,NaCl + 2\,HOH + \text{electricity} \longrightarrow 2\,NaOH + Cl_2\uparrow + H_2\uparrow$$

EXERCISES

These exercises involve the decomposition of compounds. Write the word equation and the balanced equation for each reaction.

1. Magnesium carbonate + heat ⟶
2. Aluminum chlorate + heat ⟶
3. Ferric carbonate + heat ⟶
4. Chromium hydroxide + heat ⟶
5. Carbonic acid + heat ⟶
6. Sodium chlorate + heat ⟶
7. Potassium carbonate + heat ⟶
8. Lead peroxide + heat ⟶
9. Ammonium hydroxide + heat ⟶
10. Magnesium hydroxide + heat ⟶
11. Sodium carbonate + hydrochloric acid ⟶
12. Ferric sulfite + acetic acid ⟶
13. Ammonium sulfate + sodium hydroxide ⟶
14. Aluminum carbonate + phosphoric acid ⟶
15. Potassium sulfite + sulfuric acid ⟶
16. Ammonium chloride + potassium hydroxide ⟶
17. Sulfurous acid + heat ⟶
18. Nitric acid + heat ⟶ N_2O_5 +
19. Phosphoric acid + heat ⟶ P_2O_5 +
20. Sodium sulfite + hydrochloric acid ⟶

Problem 4. How can the principles of oxidation and reduction be used in writing balanced equations?

The meaning of oxidation and reduction. When oxygen unites with copper to form copper oxide, we say that oxidation has taken place. The copper is oxidized, and the oxygen is the oxidizing agent. When a stream of hydrogen is passed over heated copper oxide, the resulting products are copper and water. Such a reaction is known as reduction. The copper oxide is reduced, and the hydrogen is the reducing agent.

With the knowledge that you now have of the electronic structure of matter and the ability that you have acquired in the writing of equations, it is now possible to explain the broader meaning of the terms *oxidation* and *reduction.*

Let us examine the equation for the reaction between copper and oxygen to determine what happens to the electrons of the elements during the reaction:

$$2\,\overset{0}{Cu} + \overset{0}{O_2} \longrightarrow 2\,\overset{2+2-}{CuO}$$

You will recall that any element in the free, uncombined state has an equal number of electrons and of protons. This explains the reason for the zero charge of copper and oxygen on the left-hand side of the equation. The reaction takes place because each oxygen atom needs two electrons to fill its outside orbit and secures these electrons from the copper. Since the copper atom lost two electrons, it now has an excess of two positive charges. For this reason, we say that copper has been oxidized. The oxygen atom, having gained two electrons, or negative charges, from the copper, has an excess of two minus charges, which represents a decrease in valence. The oxygen atom, then, is said to be reduced. The total number of electrons (4) lost by the copper atoms in this reaction is equal to the total number gained by the oxygen atoms.

Oxidation and reduction defined. When an element *increases in valence* in any chemical reaction, it is said to be *oxidized.* When an element *decreases in valence*, it is said to be *reduced.* In any chemical reaction where there has been a change in valence, the *total oxidation* always *equals* the *total reduction.*

In the broad sense, oxygen is not necessary for oxidation. For example, when silver tarnishes, the equation for the reaction is

silver oxidized—total 2 valences

$$2\,\overset{0}{Ag} + \overset{0}{S} \longrightarrow \overset{1+2-}{Ag_2S}$$

sulfur reduced—total 2 valences

In this reaction the valence of each silver atom has increased from 0 to 1 +, or a total of 2. At the same time, each sulfur atom has decreased in valence from 0 to 2 −, or a total of 2. Therefore the silver has been oxidized, the sulfur reduced, and the total oxidation equals the total reduction.

By checking the four types of equations that you have learned to write, you will discover that simple union, single replacement, and some of the decomposition equations involve oxidation and reduction. As you continue to study chemistry, you will discover that many of the common chemical reactions of everyday life are of the oxidation and reduction type. Examples are the burning of coal or wood, the rusting of iron and other metals, the decaying of plant and animal matter, and reactions involved in the taking and developing of pictures.

EXERCISES

In the oxidation-reduction reactions listed below, you should do the following things:

1. Write the word equation.
2. Balance the formula equation.
3. Place above each element its valence, being careful to observe any changes in the charge.
4. Name the element which has been oxidized and the one which has been reduced.
5. Indicate the total increase and total decrease in valence.
6. Name the oxidizing agent and the reducing agent:

Example

$$HCl + MnO_2 \longrightarrow MnCl_2 + H_2O + Cl_2\uparrow$$

1. Word equation:

Hydrochloric acid + manganese dioxide
⟶ manganese chloride + water + chlorine gas

2. $4\,HCl + MnO_2 \longrightarrow MnCl_2 + 2\,H_2O + Cl_2\uparrow$

2 Cl atoms oxidized from 1− to 0—total 2 valences

3. $4\,\overset{1+1-}{HCl} + \overset{4+2-}{MnO_2} \longrightarrow \overset{2+1-}{MnCl_2} + 2\,\overset{1+2-}{H_2O} + \overset{0}{Cl_2}$

1 atom of Mn reduced from 4+ to 2+—total 2 valences

4. The chlorine of hydrochloric acid has been oxidized from 1 − to 0. The manganese has been reduced from 4 + to 2 +.

5. The total oxidation is 2. The total reduction is 2.

6. The oxidizing agent is manganese dioxide. The reducing agent is hydrochloric acid.

$Mg + O_2 \longrightarrow MgO$

$Sb + Cl_2 \longrightarrow SbCl_3$

$Fe + I_2 \longrightarrow FeI_3$

$C + O_2 \longrightarrow CO_2$

$H_2S + O_2 \longrightarrow H_2O + SO_2$

$Ag + H_2SO_4 \longrightarrow Ag_2SO_4 + H_2O + SO_2\uparrow$

$Cu + HNO_3 \longrightarrow Cu(NO_3)_2 + H_2O + NO$

$Fe + O_2 \longrightarrow Fe_2O_3$

***Problem* 5. How can the weights of the chemicals used and produced in a chemical reaction be determined?**

Chemical weights may be determined exactly. The chemist often wishes to produce a needed product from raw materials. To do this, he must know the reaction which takes place. He must know how much of the materials to use in order to produce a desired amount of the product. His knowledge of chemical reactions enables him to write the chemical equation for the reaction. Having written the equation, he is able to calculate the amount of raw materials needed.

We have learned that a chemical equation tells us how many molecules of one raw material are needed to react with a certain number of molecules of other raw materials and how many molecules of each product are formed. Since molecules have definite weights, it is possible to determine the exact amounts of substances which go into a reaction and the exact amounts of products which are formed. This important principle makes chemistry an exact science. Let us take some examples:

Example 1. A paint-manufacturer wishes to know how many pounds of $Pb(NO_3)_2$ he will have to add in a water solution of Na_2CrO_4 to make 25 pounds of the insoluble chrome-yellow pigment ($PbCrO_4$).

Step 1. To solve this problem, write the balanced equation for the reaction.

Step 2. Under each formula, write the molecular weight times the number placed before the formula of the molecule.

Step 3. Write the known weight above the formula of the substance whose weight is known and write *x* above the formula of the substance whose weight you wish to calculate.

Step 4. Solve for *x*.

Example

Step 1. $Pb(NO_3)_2 + Na_2CrO_4 \longrightarrow 2\ NaNO_3 + PbCrO_4\downarrow$

Steps 2 and 3.

$$\underset{331}{\overset{x}{Pb(NO_3)_2}} + \underset{162}{Na_2CrO_4} \longrightarrow \underset{85 \times 2}{2\ NaNO_3} + \underset{323}{\overset{25\text{ pounds}}{PbCrO_4\downarrow}}$$

Step 4. $\frac{x}{331} = \frac{25}{323}$

Solving for *x*:

$323\,x = (331 \times 25)$

$323\,x = 8275$

$x = 25.62$ pounds of $Pb(NO_3)_2$ needed

Example 2. How many pounds of Na_2CrO_4 will be needed to react with the 25.6 pounds of $Pb(NO_3)_2$ to produce 25 pounds of $PbCrO_4$?

$$\underset{331}{Pb(NO_3)_2} + \underset{162}{\overset{x}{Na_2CrO_4}} \longrightarrow \underset{85 \times 2}{2\ NaNO_3} + \underset{323}{\overset{25\text{ pounds}}{PbCrO_4}}$$

$$\frac{x}{162} = \frac{25}{323}$$

$323\,x = 25 \times 162 = 4050$

$x = 12.53$ pounds of Na_2CrO_4 needed

Example 3. How many pounds of $NaNO_3$ are produced?

$$Pb(NO_3)_2 + Na_2CrO_4 \longrightarrow \underset{85 \times 2}{\overset{x}{2\ NaNO_3}} + \underset{323}{\overset{25\text{ pounds}}{PbCrO_4\downarrow}}$$

$$\frac{x}{170} = \frac{25}{323}$$

$323\,x = 4250$

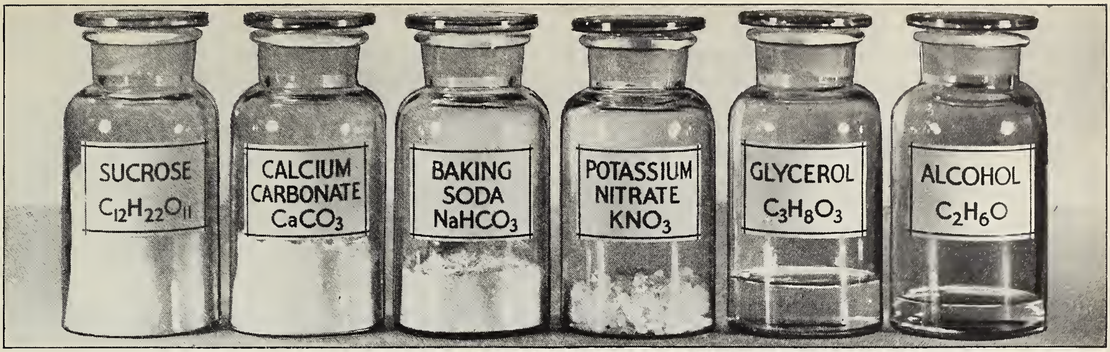
$x = 13.15$ pounds of $NaNO_3$ produced

Note that the total weight of reacting substances equals the total weight of the products formed.

$Pb(NO_3)_2$ = 25.62 pounds
Na_2CrO_4 = 12.53 pounds
Total weight of reacting substances = 38.15 pounds

$NaNO_3$ = 13.15 pounds
$PbCrO_4$ = 25.00 pounds
Total weight of products = 38.15 pounds

In the problem above, the pound was the unit of weight. Since atomic and molecular weights are



Each of these bottles contains a gram-molecular weight of the substance indicated on the label. How many grams of each compound are in each bottle?

relative weights, we may use any unit of weight, provided we use the same unit throughout the problem, whether it be gram, kilogram, ton, or pound.

EXERCISES

1. (*a*) How many ounces of mercury are produced by decomposing 16 ounces of mercuric oxide? (*b*) How many ounces of oxygen are produced?

2. How many grams of zinc are necessary, when reacting with sufficient sulfuric acid, to produce 56 grams of hydrogen?

3. How many grams of carbon dioxide will be produced by the complete combustion of 14 grams of carbon?

4. How many pounds of baking soda must be decomposed by heat to produce 3 pounds of washing soda? Assume the products of this reaction to be Na_2CO_3, CO_2, and H_2O.

5. How many grams of ammonia gas are produced when 96 grams of slaked lime react with sufficient ammonium chloride?

6. The following equation represents one method of preparing chlorine:

$$4\,HCl + MnO_2 \longrightarrow MnCl_2 + 2\,H_2O + Cl_2\uparrow$$

How many grams of chlorine will be produced when 48 grams of hydrochloric acid react with sufficient manganese dioxide?

7. What weight of silver will be precipitated when 4 ounces of copper are placed in a solution of silver nitrate?

8. What weight of magnesium metal must be burned in air to produce 8 grams of magnesium oxide?

Problem 6. How may the volumes of the gases used and produced in a chemical reaction be determined?

What is gram-molecular volume? Very often the chemist wants to know the volumes of the gases used or produced in a chemical reaction rather than the weight of these gases. This is very easy for him to know if he understands what is meant by gram-molecular volume.

The gram-molecular weight of a gas is its molecular weight in grams. Thus the molecular weight of oxygen is 32, and its gram-molecular weight is 32 grams. When the gram-molecular weight of oxygen is divided by the weight of 1 liter of oxygen $\left(\frac{32}{1.429}\right)$, the result, 22.4 liters, is called the *gram-molecular volume* of oxygen.

Similarly, the gram-molecular volume of hydrogen may be obtained by dividing the gram-molecular weight of hydrogen by the weight of a liter of hydrogen $\left(\frac{2}{.08987}\right)$, and again the result is 22.4 liters. Further computations, with other gases, will show that a gram-molecular weight of any gas under standard conditions of temperature (0° C) and pressure (760 millimeters—abbreviated mm) occupies 22.4 liters of volume. This may be expressed as follows:

$$\underset{\text{(of any gas)}}{\text{Molecular weight}} = \underset{\text{(of the gas)}}{\text{weight of 1 liter}} \times 22.4 \text{ liters}$$

Wherever volumes of gases are to be used or found in a calculation, 22.4 liters may be used as the equivalent of 1 gram-molecular weight of a gas.

The following examples will illustrate how this information may be used in solving problems:

Example 1. How many liters of NH_3 will be produced from a reaction between 100 grams of $(NH_4)_2SO_4$ and a sufficient amount of slaked lime to complete the reaction?

Step 1. Write and balance the equation.

$$(NH_4)_2SO_4 + Ca(OH)_2 \longrightarrow CaSO_4 + 2\,HOH + 2\,NH_3\uparrow$$

Step 2. Write the known weight (100 grams) above the $(NH_4)_2SO_4$ and x liters above the NH_3.

$$\overset{100}{(NH_4)_2SO_4} + Ca(OH)_2 \longrightarrow CaSO_4 + 2\,HOH + 2\,\overset{x}{NH_3}\uparrow$$

Step 3. Write the molecular weight below the $(NH_4)_2SO_4$; and below the $2\,NH_3$ write the gram-molecular volume (22.4 liters) *times* the *number* of *molecules* (2) and solve for x.

$$\underset{132}{\overset{100\text{ grams}}{(NH_4)_2SO_4}} + Ca(OH)_2 \longrightarrow CaSO_4 + 2\,HOH + \underset{2\,(22.4)}{\overset{x\text{ liters}}{2\,NH_3}}\uparrow$$

$$\frac{100}{132} = \frac{x}{44.8}$$

$$132\,x = 4480$$

$x = 33.93$ liters of NH_3 at S.T.P. (standard temperature and pressure)[1]

Example 2. What weight of potassium chlorate must be heated to produce 12 liters of oxygen?

Step 1. Write and balance the equation.

$$2\,KClO_3 \longrightarrow 2\,KCl + 3\,O_2\uparrow$$

Step 2. Write x for the unknown weight and write the known volume of the gas above the formulas involved. Cross out the formula not used.

$$\overset{x\text{ grams}}{2\,KClO_3} \longrightarrow 2\,KCl + \overset{12\text{ liters}}{3\,O_2}$$

Step 3. Write the molecular weight and gram-molecular volume times the number of molecules below the formulas involved.

$$\begin{array}{ccc} x\text{ grams} & & 12\text{ liters} \\ 2\,KClO_3 & \longrightarrow 2\,KCl + & 3\,O_2 \\ 2(39 + 35.5 + 48) & & 3(22.4) \\ 245 & & 67.2 \end{array}$$

Step 4. Form the mathematical equation and solve for x.

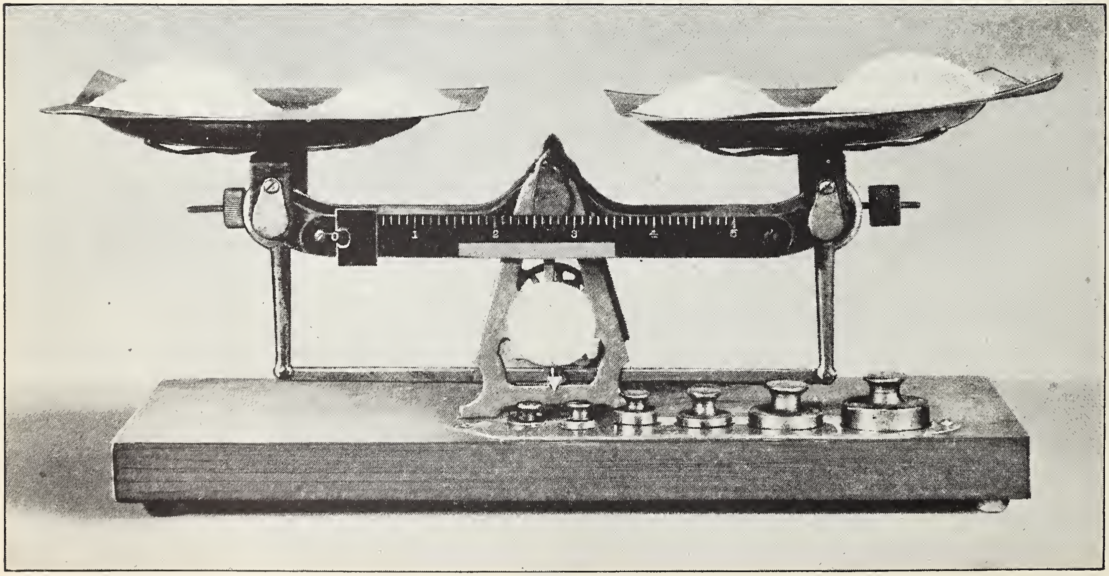
$$\frac{x}{245} = \frac{12}{67.2}$$

$$67.2\,x = 12 \times 245$$

$$x = \frac{12 \times 245}{67.2} = 43.7 \text{ grams of } KClO_3$$

Since the gram-molecular volume is expressed in liters, the weights used must be expressed in grams.

In any chemical reaction the total weight of the reacting substances is always equal to the weight of the products formed



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[1] You can learn how to make corrections in the volumes of gases when the temperature and pressure are not standard by consulting the Appendix (pp. i–iii). Your teacher may wish you to work the problems in the Appendix at this time.

The law of combining volumes—Gay-Lussac's law. The French chemist Gay-Lussac (1778–1850), in his study of gases, found that two volumes of hydrogen unite with one volume of oxygen to form two volumes of water vapor, provided all measurements are made at the same temperature and pressure. He also found that two volumes of nitric oxide (NO) unite with one volume of oxygen (O_2) to form two volumes of nitrogen dioxide (NO_2). These and other examples may be expressed in this manner:

$$\begin{array}{cccccc} \text{Hydrogen} & + & \text{oxygen} & \longrightarrow & \text{water vapor} \\ 2\,H_2 & + & O_2 & \longrightarrow & 2\,H_2O \\ 2\text{ molecules} & + & 1\text{ molecule} & \longrightarrow & 2\text{ molecules} \\ 2\text{ volumes} & + & 1\text{ volume} & \longrightarrow & 2\text{ volumes} \\ \text{Nitric oxide} & + & \text{oxygen} & \longrightarrow & \text{nitrogen dioxide} \\ 2\,NO & + & O_2 & \longrightarrow & 2\,NO_2 \\ 2\text{ molecules} & + & 1\text{ molecule} & \longrightarrow & 2\text{ molecules} \\ 2\text{ volumes} & + & 1\text{ volume} & \longrightarrow & 2\text{ volumes} \end{array}$$

The relationship between the reacting volumes of hydrogen and nitrogen may be shown as follows:

$$\begin{array}{cccccc} \text{Nitrogen} & + & \text{hydrogen} & \longrightarrow & \text{ammonia} \\ N_2 & + & 3\,H_2 & \longrightarrow & 2\,NH_3 \\ 1\text{ molecule} & + & 3\text{ molecules} & \longrightarrow & 2\text{ molecules} \\ 1\text{ volume} & + & 3\text{ volumes} & \longrightarrow & 2\text{ volumes} \end{array}$$

Gay-Lussac was surprised to find that the volumes of reacting gases always combine in a ratio which can be expressed in small whole numbers. This fact is now expressed in a statement known as Gay-Lussac's law (formulated in 1808).

When two gases combine chemically, there is always a ratio of small whole numbers between the volumes that combine, as well as between the volume of either of them and that of the product (provided it is a gas).

Avogadro's law. The great Italian scientist Avogadro (1776–1856) was greatly impressed by the relationship between the volumes of reacting gases as discovered by Gay-Lussac. He was puzzled as to why this relationship existed and, after studying the problem, decided that "*equal volumes of all gases, measured under the same conditions of temperature and pressure, contain the same number of molecules.*" He could not prove this statement, but we now know it to be true and call it *Avogadro's law.* This law enables us to explain why Gay-Lussac's law is true.

Avogadro's law is one of the fundamental laws of chemistry, since it enables the scientist to measure the relative weights of molecules.

We can now see why it is that 22.4 liters of any gas at a given temperature and pressure will contain the same number of molecules as any other gas under the same conditions. This also explains why the weight in grams of 22.4 liters of any gas at standard temperature and pressure is numerically the same as its molecular weight.[1]

Problems involving volumes only. The following example will show how the laws explained above help us to solve certain problems:

Example. How many liters of ammonia gas are formed by a reaction between 8 liters of hydrogen and a sufficient amount of nitrogen to complete the reaction?

Step 1. Write the balanced equation.

$$N_2 + 3\,H_2 \longrightarrow 2\,NH_3$$

The following facts are known:

$$1\text{ molecule of }N_2 + 3\text{ molecules of }H_2 \longrightarrow 2\text{ molecules of }NH_3$$

$$1\text{ volume of }N_2 + 3\text{ volumes of }H_2 \longrightarrow 2\text{ volumes of }NH_3$$

$$1\text{ liter of }N_2 + 3\text{ liters of }H_2 \longrightarrow 2\text{ liters of }NH_3$$

Step 2. Place x above the formula of the gas whose volume we wish to find and 8 above the formula of the gas whose volume (in liters) we know (H_2).

$$N_2 + \overset{8}{3\,H_2} \longrightarrow \overset{x}{2\,NH_3}$$

Step 3. Make the proportion and solve for x.

$$\frac{8}{3} = \frac{x}{2}$$

$$3\,x = 16$$

$$x = 5.33\text{ liters of }NH_3\text{ formed}$$

Any unit of volume may be used in this type of problem, since weights are not involved.

EXERCISES

1. Pure sulfur is burned in 8 liters of oxygen. (*a*) How many liters of sulfur dioxide are produced? (*b*) How many grams of sulfur are used?

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[1] Other gas laws are discussed in the Appendix. Your teacher may wish you to study these laws and work the problems found there.

2. How many liters of hydrogen sulfide are produced when 12 grams of ferrous sulfide react with sufficient hydrochloric acid?

3. The following equation represents one method of preparing chlorine:

$$CaOCl_2 + H_2SO_4 \longrightarrow CaSO_4 + H_2O + Cl_2$$

How many grams of bleaching powder are necessary to make 6 liters of chlorine?

4. (*a*) How many liters of hydrogen are necessary to react with sufficient chlorine to produce 12 liters of hydrogen chloride? (*b*) How many liters of chlorine are used?

5. If 1 liter of a gaseous element weighs 1.25 grams under S.T.P. (standard temperature and pressure), what is the molecular weight of the element? What element do you think this gas is?

6. (*a*) What will 1500 liters of HCN gas weigh at S.T.P.? (*b*) What will 2240 liters of N_2O weigh at S.T.P.?

7. How many liters of oxygen will be needed to burn 100 liters of carbon monoxide?

8. The chief constituent of natural gas is methane (CH_4). Calculate the cubic feet of air necessary to burn 10,000 cubic feet of methane. (Assume that air is 21 per cent oxygen.)

9. (*a*) What weight of CO_2 will be produced when 100 grams of carbon are burned? (*b*) What will be the volume of this gas?

10. Calculate the volume of (*a*) 26 grams of acetylene gas (C_2H_2); (*b*) 50 grams of ammonia (NH_3); (*c*) 100 grams of NO_2; (*d*) 355 grams of chlorine.

11. A chemist burns 10 grams of coal and finds that it produces 29 grams of carbon dioxide. (*a*) What weight of carbon was consumed when the coal burned? (*b*) What was the percentage of carbon in the coal?

12. A student heats 25 grams of mercuric oxide in the laboratory until it has been completely decomposed. (*a*) What will be the weight of mercury left in the test tube? (*b*) What will be the volume of the oxygen evolved at S.T.P.?

13. How many grams of silver sulfide will be precipitated when 100 liters of pure H_2S are run into $AgNO_3$? (Assume that the reaction is complete.)

$$2\ AgNO_3 + H_2S \longrightarrow Ag_2S\downarrow + 2\ HNO_3$$

14. How many liters of CO_2 will be produced when 1 kilogram (abbreviated kg) of limestone is heated?

$$CaCO_3 + \text{heat} \longrightarrow CaO + CO_2\uparrow$$

UNIT EXERCISES

Write balanced equations for each of the following:

1. Phosphorus + oxygen →
2. Zinc + lead acetate →
3. Antimony + oxygen →
4. Aluminum + sulfur →
5. Hydrogen + chlorine →
6. Magnesium + silver nitrate →
7. Calcium hydroxide + sodium phosphate →
8. Sodium arsenate + lead acetate →
9. Bismuth sulfate + potassium silicate →
10. Ferric carbonate + heat →
11. Chromium sulfite + hydrogen chloride →
12. Mercurous nitrate + barium chloride →
13. Ammonium phosphate + magnesium hydroxide →
14. Zinc chlorate + heat →
15. Stannic hydroxide + heat →
16. Magnesium ribbon burning in air →
17. Electrolysis of water →
18. Strontium nitrate + aluminum sulfate →
19. Potassium + water →
20. Hydrogen sulfide + oxygen → $H_2O + SO_2$
21. Sodium chloride + sulfuric acid →
22. Aluminum iodide + bromine →
23. Silver sulfate + aluminum →
24. Potassium chloride + electricity →
25. Electrolysis of $CuCl_2$ →

REFERENCES FOR FURTHER READING

Jaffe, Bernard. *Chemical Calculations.* World Book Company, Yonkers-on-Hudson, New York, 1931.

Kendall, James. *At Home among the Atoms.* D. Appleton-Century Company, Inc., New York, 1929.

UNIT 10

Acids, Bases, Salts, and Oxides

It is necessary to classify compounds in chemistry. There are some thirty thousand separate, different compounds in the realm of inorganic chemistry. You can readily see that it is humanly impossible to learn much about all these separate compounds unless we classify them into groups. All the individual compounds in a group exhibit chemical and physical properties which enable us to recognize them as belonging to that group. Chemists classify these groups of compounds as acids, bases, salts, and oxides. The compounds of these groups, together with the 92 elements, make up the inorganic chemical world. Elements cannot be brought into the classifications of acids, bases, salts, and oxides, because they are not compounds.

You must remember that the materials which we use and come in contact with daily are not all inorganic. Generally speaking, however, it is possible to classify every pure compound, except some of the carbon compounds, under one of the four groups given above. The carbon compounds are closely related to life and living processes and therefore are called *organic* compounds. There are some exceptions, since chemically there is no sharp division between living and nonliving substances. For example, $CaCO_3$ (calcium carbonate, or limestone) is commonly called an inorganic salt; yet it contains the element carbon. There are more than five hundred thousand different organic substances, some of which will be discussed later.

An understanding of acids, bases, salts, and oxides will come gradually. Do not expect to learn all there is to know about this phase of your work at this point. Enough information will be given so that you will be able to read understandingly the latter part of this book, which deals with practical chemistry. One of the objectives of this course in chemistry is the gaining of an accurate knowledge of the material world. An understanding of the fundamentals of chemistry, which includes an understanding of acids, bases, salts, and oxides, will help you to achieve this objective.

PURPOSES TO BE ACHIEVED

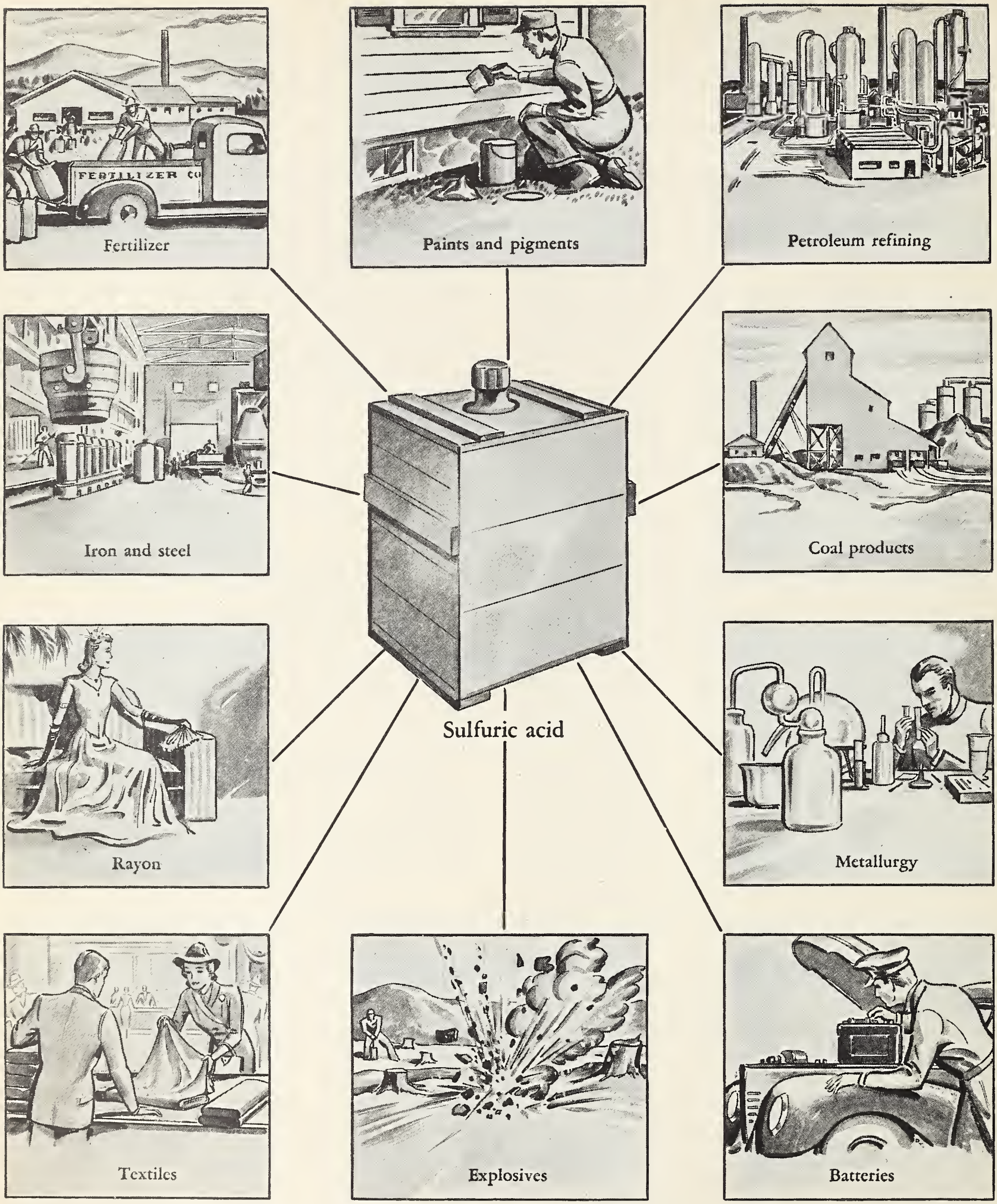
1. To learn how the chemist classifies the thousands of substances in an orderly, definite manner.
2. To become familiar with and to recognize acids, bases, salts, and oxides.
3. To learn general methods of preparing the compounds of each of these groups.
4. To become aware of the use of many of these compounds in daily living.

PROBLEMS TO BE SOLVED

1. What are acids, and where do we find them?
2. What should we know about the common acids?
3. How are acids prepared?
4. What are hydroxides?
5. What are the general properties of bases?
6. What should we know about some of the common bases?
7. What are salts, and why are they important to us?
8. How are salts formed?
9. How are salts named, and how are they classified?
10. What are the properties of salts?
11. What are oxides?

Problem 1. What are acids, and where do we find them?

Acids, the sour-tasting compounds. If you were asked to describe the taste of a number of substances such as vinegar, orange juice, and lemon juice, you would say that they are all sour. Many substances exhibit this property of sourness, and a chemical analysis of them shows that they all contain substances called acids. Cream sours and butter becomes rancid because of the formation of acids. The storage battery of your car contains an acid. Acids are used in cleaning construction materials, such as brick. Many foods, such as corn sirup and beet sugar, are prepared or purified by



Sulfuric acid plays an important part in the manufacture of many commonly used materials acids. The silverware which you use every day is made by means of acids and tarnishes because of an acid. Acids are a class of compounds that have been recognized since ancient times because they taste sour when in dilute solution. *Acidus* is the Latin word for "sour." Sulfuric acid (H_2SO_4), hydrochloric acid (HCl), and nitric acid (HNO_3) are the most commonly used acids; they were discovered and used in the days of alchemy. In addition to the physical property of sourness, acids possess other properties which chemists use to identify them. In order to understand thoroughly this important class of inorganic compounds, we shall need to study these properties.

Acids have a common element. That element is hydrogen. However, do not think that all compounds which contain hydrogen are acids. To class a compound as an acid the hydrogen of the compound must be able to break apart from the rest of the molecule and exist as an H^{1+} ion when the substance is dissolved in water. Chemically, *an acid is a compound whose water solution produces hydrogen* (H^+) *ions as the only positive ions in the solution.* The following ionization equations will illustrate how some of the common acids ionize in dilute solutions:

$$H_2SO_4 \text{ ionizes} \longrightarrow 2\,\overset{1+}{H} + \overset{2-}{(SO_4)}$$

$$HCl \text{ ionizes} \longrightarrow \overset{1+}{H} + \overset{1-}{Cl}$$

$$HNO_3 \text{ ionizes} \longrightarrow \overset{1+}{H} + \overset{1-}{NO_3}$$

$$HF \text{ ionizes} \longrightarrow \overset{1+}{H} + \overset{1-}{F}$$

$$H_2CO_3 \text{ ionizes} \longrightarrow 2\,\overset{1+}{H} + \overset{2-}{(CO_3)}$$

$$H_3PO_4 \text{ ionizes} \longrightarrow 3\,\overset{1+}{H} + \overset{3-}{(PO_4)}$$

$$HC_2H_3O_2 \text{ ionizes} \longrightarrow \overset{1+}{H} + \overset{1-}{(C_2H_3O_2)}$$

Notice that all these acids produce hydrogen ions as the only positive ions.

Indicators are affected in the same way by all acids. An indicator is a substance that changes color when in the presence of a base or an acid. The extract from purple cabbage leaves and a lichen substance called litmus turn red when in the presence of an acid. Litmus is the common indicator that you will use to identify acids. Some of the common indicators are affected by acids as follows:

The sour taste of these common products, found in the home, is due to the acid they contain

1. Acids turn blue litmus red.
2. Acids turn methyl orange pink in color.
3. Acids do not change the color of phenolphthalein.

Most acids act upon most metals. If the metal is more active than hydrogen, the hydrogen ion of the acid receives the electron from the metallic atom and becomes hydrogen gas. The metal forms a metallic salt in the solution by uniting with the negative ion of the acid. For example:

$$2\,Al + 6\,HCl \longrightarrow 2\,AlCl_3 + 3\,H_2\uparrow$$

$$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2\uparrow$$

The sulfuric and hydrochloric acids must be dilute for this type of reaction. When the acid is dissolved in water, the hydrogen ion is freed from the negative ion and is displaced by the metal if the metal is more active chemically.

Some acids in a concentrated state will corrode metals, even though the metals are less active than hydrogen. These reactions are called oxidation-reduction reactions, and acids which are capable of reacting with metals less active than hydrogen are called oxidizing acids. For example, if a silver ring were put in concentrated nitric acid, this reaction would take place:

silver + nitric acid ⟶ silver nitrate + water + nitrogen dioxide

$$AG + 2HNO_3 \longrightarrow AgNO_3 + H_2O + NO_2\uparrow$$

Silver is oxidized to a 1 + valence, and some of the nitrogen of nitric acid is reduced from a 5 + valence in the nitric acid to a 2 + valence in the nitric oxide. Most metals are affected this way by strong concentrated acids which contain oxygen. The metallic salt of the acid is always formed, and H_2O and a gas are given off.

Acids neutralize hydroxides, or bases. Neutralization results when an acid reacts with a metallic hydroxide or metallic oxide. Water is always formed in this type of reaction. Such reactions will be further explained under the subject of bases. Examples of this property are

$$HCl + NaOH \longrightarrow NaCl + HOH$$

$$2\ HC_2H_3O_2 + CaO \longrightarrow Ca(C_2H_3O_2)_2 + H_2O$$

Acids act upon carbonates. When an acid acts upon carbonate salts, carbonic acid is produced. When carbonic acid is produced, it decomposes and forms water and carbon dioxide. Therefore, when an acid is added to a carbonate salt, the evolution of carbon dioxide is always the result. An example of this type of reaction is

$$2\ HCl + CaCO_3 \longrightarrow CaCl_2 + H_2CO_3$$
$$\longrightarrow CaCl_2 + H_2O + CO_2$$

All carbonates are acted upon by acids in this manner, and because of this action their presence is detected in unknown compounds by adding an acid to the compound.

Strength of acids. An acid is said to be a strong acid when a large percentage of its molecules break up into ions in dilute solution. On the other hand, an acid whose molecules dissociate very little in solution is a weak acid. Nitric, hydrochloric, and sulfuric acids are strong acids, while boric, acetic, and carbonic acids are weak acids.

It is important that you do not confuse the terms *strong* and *concentrated* when applied to acids. A concentrated acid is a solution in which a large amount of the acid is dissolved in a small amount of water. Thus concentrated sulfuric acid is generally 98 per cent acid and 2 per cent water, and concentrated acetic acid is 99 per cent acid and 1 per cent water. However, sulfuric acid is a strong acid because in dilute solution it will ionize to the extent of 61 per cent, while acetic acid is a weak acid because only 1.3 per cent of its molecules will ionize in dilute solution. Therefore a concentrated acid may be a weak or a strong acid.

EXERCISES

1. Copy the following table and write in the spaces the products formed when the dilute acids are added to the metals. (Metals do not liberate hydrogen from HNO_3 (nitric acid) unless the acid is extremely dilute.) *Do not write in this book.*

	Fe	Zn	Al	Mg
HCl	$FeCl_2 + H_2$			
H_2SO_4				
$HC_2H_3O_2$				
H_3PO_4				

2. Describe the reaction that occurs when tomatoes or foods containing vinegar are cooked in aluminum pans. Is this desirable? Explain.

3. Write the names of the compounds that are formed in Exercise 2, assuming that the acids are acetic and citric.

4. What are the chemical properties of acids?

5. What determines the strength of an acid?

6. What is the difference between a strong acid and a concentrated acid?

7. Write the equation for the action of sulfuric acid upon sodium carbonate.

8. How could you test an unknown compound for the presence of carbonates?

9. When you apply ammonium hydroxide to hydrochloric acid which has been spilled on your clothing, what reaction takes place? Write the equation for this reaction.

10. List three strong acids and three weak acids. Explain why they are classed as strong or weak.

Problem 2. What should we know about the common acids?

Organic and inorganic acids. There are two big classes of acids. They are called organic acids and inorganic acids. This classification depends on the presence or absence of the element carbon. Organic acids always contain carbon, and the common ones do not furnish many hydrogen ions per unit volume when in water solution. Inorganic acids, as a rule, *Some Well-Known Acids (Inorganic and Organic)*

Chemical Name	Formula	Common Name or Source	Solubility	Ionization	Strength
Nitric	HNO_3	Aqua fortis (strong water)	Very soluble	Ionizes well in dilute solution; dissociation = 93 per cent	Very strong
Hydrochloric	HCl	Muriatic	Very soluble	Ionizes well in dilute solution; dissociation = 92 per cent	Very strong
Sulfuric	H_2SO_4	Oil of vitriol	Very soluble	Ionizes well; dissociation = 65 per cent–90 per cent	Very strong
Hydrofluoric	HF	Etching acid	Soluble	Ionizes	Moderate
Hydrobromic	HBr		Soluble	Ionizes well	Strong
Hydriodic	HI		Soluble	Ionizes well	Strong
Phosphoric	H_3PO_4	Acid phosphate	Soluble	Ionizes moderately	Weak
Acetic	$HC_2H_3O_2$	The acid of vinegar	Soluble	Ionizes slightly	Weak
Boric	H_3BO_3		Slightly soluble	Ionizes feebly	Very weak
Sulfurous	H_2SO_3		Soluble	Ionizes slightly	Weak
Malic	$H_2C_4H_4O_5$	Present in apples	Slightly soluble	Ionizes feebly	Very weak
Citric	$H_3C_6H_5O_7$	Present in lemons	Slightly soluble	Ionizes feebly	Very weak
Tartaric	$H_2C_4H_4O_6$	Present in grapes	Slightly soluble	Ionizes feebly	Very weak
Hydrocyanic	HCN	Prussic acid	Soluble	Ionizes slightly	Weak but very poisonous
Hydrosulfuric	H_2S	Hydrogen sulfide	Soluble	Ionizes	Weak but poisonous

ionize readily and usually furnish many hydrogen ions per unit volume. Inorganic acids are termed mineral acids by many writers because they can be obtained from minerals. For the present, we will deal mostly with the inorganic, or mineral, acids. The table at the top of this page lists many acids, with some interesting facts and properties of each of them. You will need to refer to this table many times as you continue the study of chemistry.

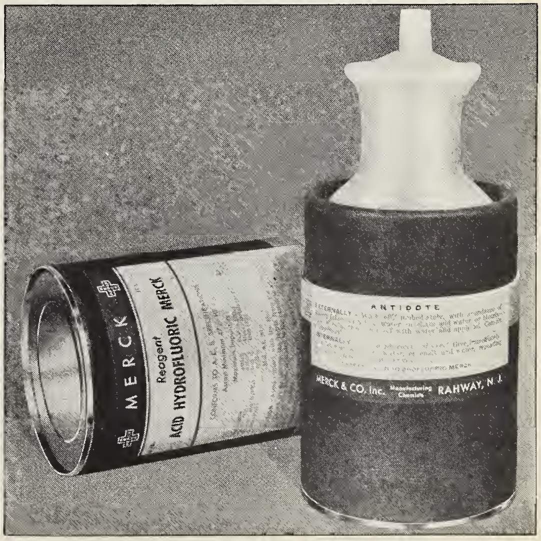
Acids which contain two elements. Acids which contain hydrogen combined with a nonmetal are known as *binary* acids. Before we study each of several of these acids, it is important that you understand the rules for naming them. Binary acids are named by placing the prefix *hydro* before and the suffix *ic* after a stem of the name of the nonmetal. Thus HCl is called *hydro*chlor*ic* acid. Other important binary acids are hydrosulfuric (H_2S) and hydrofluoric (HF).

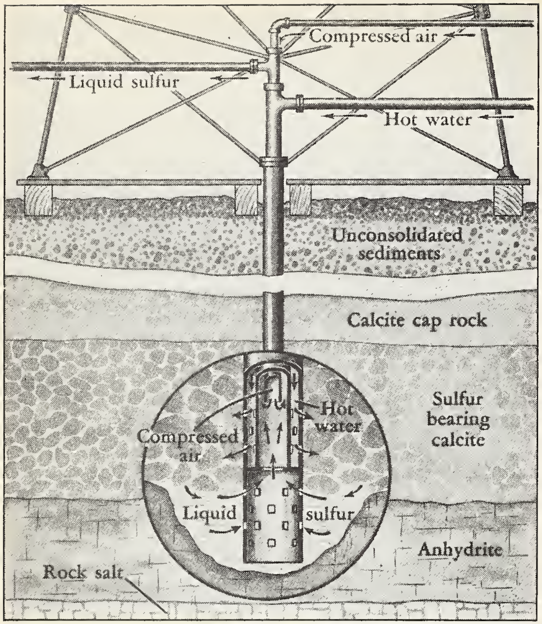
Hydrochloric acid, the acid which aids in food digestion. You will use hydrochloric acid a great deal, as it is a common laboratory acid. In the preparation of this acid, we first obtain the gas hydrogen chloride (HCl), which is extremely soluble in water. Hydrogen chloride gas, when dissolved in water, produces hydrochloric acid (HCl).

Hydrochloric acid is found in the stomach. The gastric juice contains about a 0.3 per cent solution of the acid, which is necessary for the complete digestion of foods. Another use of hydrochloric acid is in the manufacture of corn sirup and glucose from cornstarch. It is also used to clean metals in soldering and galvanizing iron. In the laboratory you will use it in the preparation of hydrogen gas. The impure form, known as muriatic acid, is used by masons to clean the mortar from brick and stone.

Other binary acids. Hydrogen sulfide (H_2S) is the rather foul-smelling gas that you no doubt have

Why must hydrofluoric acid be kept in a wax bottle?





Texas Gulf Sulphur Company, Inc.

Sulfur is melted by the hot water and raised to the surface by compressed air

detected around sulfur water springs. It is also well known as the gas of rotten eggs. Dissolved in water, it makes hydrosulfuric acid, a common reagent.

Hydrofluoric acid (HF) is used to etch glass. Electric-light bulbs are frosted with this acid. It has to be kept in wax containers because of its action on glass. This acid should be *handled with extreme care*; it produces severe burns if it touches the skin, and its fumes are deadly.

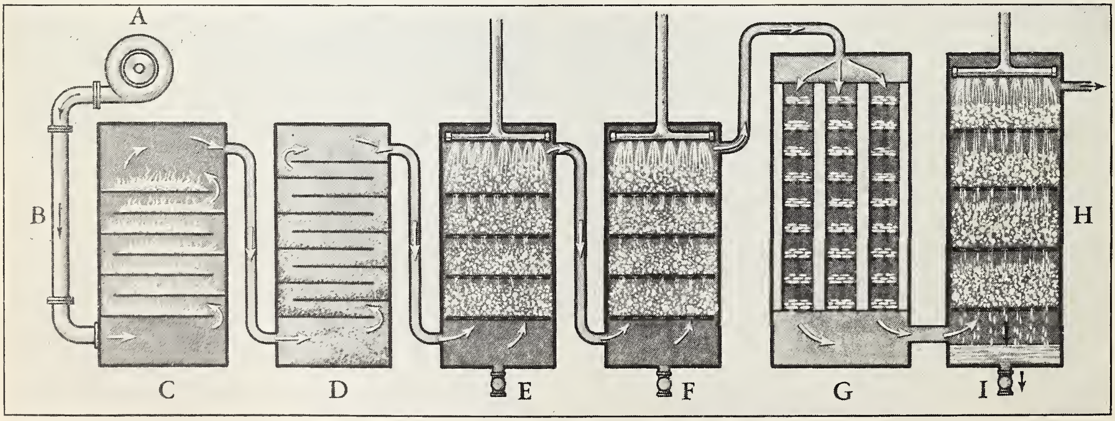
Acids which contain more than two elements. *Ternary* acids contain hydrogen, a nonmetal, and usually oxygen. These are far more numerous than the binary, or two-element, acids. Examples:

H_2SO_4—sulfuric
H_2SO_3—sulfurous
HNO_3—nitric
HNO_2—nitrous
H_3PO_4—phosphoric
H_3PO_3—phosphorous
H_2CO_3—carbonic
$HC_2H_3O_2$—acetic

It is important that you understand how these acids are named. Ternary acids are named by adding *ic* or *ous* to a stem of the name of the nonmetal or to the name of the nonmetal itself. They end in *ic* if the nonmetal is displaying its usual valence (positive) and in *ous* if the nonmetal uses its next lowest valence. You will notice also that the *ic*-acids contain one more atom of oxygen than the *ous*-acids. For example, H_2SO_4 is sulfur*ic* and H_2SO_3 is sulfur*ous*. The valence of sulfur in the former is 6 and in the latter is 4.

Sulfuric acid, the index to civilization. Many of the ternary acids are very important to us. Sulfuric acid (H_2SO_4) is the acid that you will use more than any other in the laboratory. In addition, it is so important in our industrial life that some writers have said that the height of the civilization of a

Contact process for manufacturing sulfuric acid. Air is forced by the blower *A* through *B* into *C*, where the sulfur is burned to SO_2. The sulfur dioxide gas is cleaned in *D* and dried with a spray of concentrated sulfuric acid in *E* and *F*. In the presence of a catalyst, sulfur dioxide combines with oxygen to form SO_3 (*G*). The SO_3 is absorbed by concentrated H_2SO_4 in *H* and the fuming acid withdrawn at *I*



Texas Gulf Sulphur Company

Molten sulfur is piped from sulfur wells into huge vats, where it solidifies. This vat has been blasted, and the sulfur is being loaded for shipment to the market

country could be measured by the amount of sulfuric acid that the country used. This acid is made commercially by the lead-chamber and the contact process (see diagram on preceding page). The United States produces and uses more than 2,000,000 tons of it annually. It is used in the textile industry, in making rayon, in refining gasoline and lubricating oils, in electroplating, in making corn sirup, in making paper, in making explosives, such as dynamite and TNT, and in making fertilizers. Its use affects directly or indirectly nearly everything that we use in everyday life.

Nitric acid—the raw material used in making explosives and fertilizers. Nitric acid (HNO_3) contains the element nitrogen in combined form, and it is because this element possesses important chemical properties that the acid and its compounds are widely used. Since nitrogen tends to exist in the free state, its compounds are very unstable and are therefore used as the base of most explosives. Most high explosives are made by combining various compounds with nitric acid.

Nitric acid may be used in making nitrate fertilizers which are necessary for plant growth, and therefore it is valuable to farmers. Therefore, again, we can say that our present high standards of living are dependent upon our having available a sufficient amount of nitric acid. It has been said that nitrogen and its compounds can serve as the destroyer and also as the preserver of mankind. Can you explain definitely how this statement is true?

Carbonic acid, an acid we drink. Carbonic acid (H_2CO_3) is the acid in carbonated beverages which gives them their pleasantly sour and sharp taste. It is an acid that rapidly decomposes according to the following equation:

$$H_2CO_3 \longrightarrow H_2O + CO_2\uparrow$$

This reaction accounts for many of its properties and uses. The reverse of this equation shows how it is made:

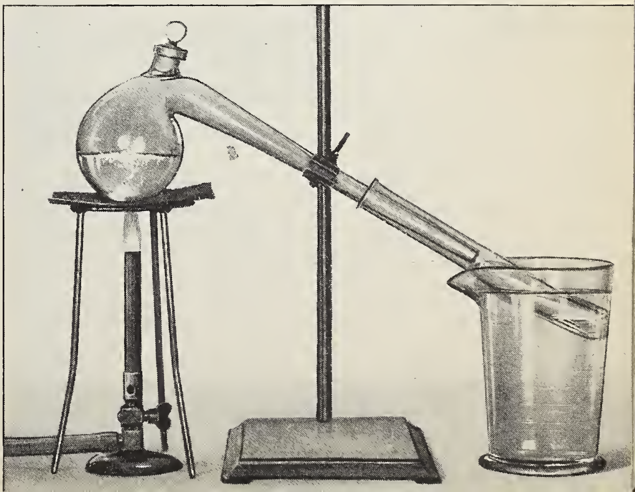
$$CO_2 + H_2O \longrightarrow H_2CO_3$$

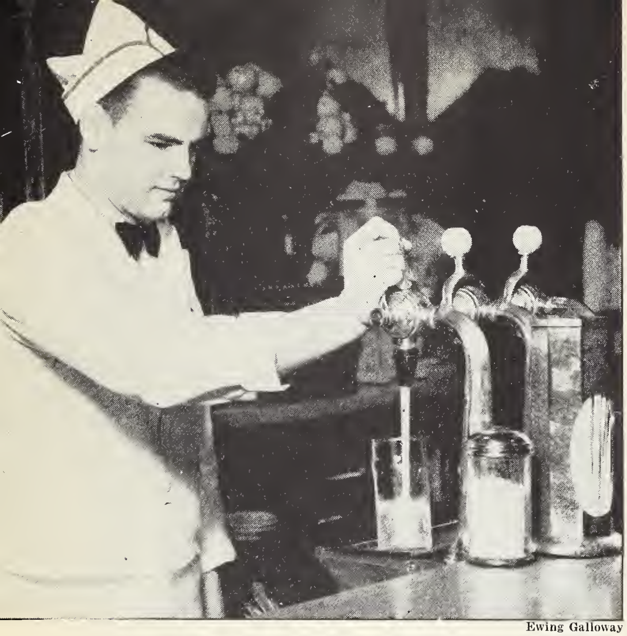
Every time carbon dioxide gas is passed into water, carbonic acid is produced. It is constantly being made and being decomposed in the atmosphere. You will understand this if you recall that the components of this acid are always in the air. Since there is always carbon dioxide in the air, and there is water in streams, therefore a weak solution of H_2CO_3 is always present in natural waters. This fact plays a big part in the erosion of soil and in cave formation.

The acids H_2SO_3 and H_2CO_3 exist only in water solution and are produced by the action of sulfur dioxide and carbon dioxide upon water. These acids cannot be isolated and obtained in the solid, liquid, or gaseous state.

Acetic acid, the acid of vinegar. Acetic acid ($HC_2H_3O_2$, or CH_3COOH) is really not an inorganic, or mineral, acid, but rather is classed as an organic acid. However, it is used so frequently in inorganic chemical laboratories that it will be dis-

Nitric acid may be prepared in the laboratory by heating a mixture of sodium nitrate and concentrated sulfuric acid in a retort, as shown in the diagram. The equation for this reaction is $NaNO_3 + H_2SO_4 \longrightarrow NaHSO_4 + HNO_3$





Ewing Galloway

Carbonated beverages contain carbonic acid, which gives them a pleasant sour taste

cussed here. It is produced by the fermentation of fruit juices, caused by the action of certain bacteria on the sugars which are in solution.

$$\begin{array}{l} \text{fruit sugar} + \text{yeast} \longrightarrow \text{ethyl alcohol} + \text{carbon dioxide} \\ C_6H_{12}O_6 + \text{yeast} \longrightarrow 2C_2H_5OH + 2CO_2 \end{array}$$

$$\begin{array}{l} \text{ethyl alcohol} + \text{oxidation} \longrightarrow \text{acetic acid} + \text{water} \\ C_2H_5OH + O_2 \longrightarrow CH_3COOH + H_2O \end{array}$$

Commercial acetic acid was formerly produced synthetically as a by-product in the destructive distillation of wood. More recently it has been synthesized from acetylene by a series of oxidation processes.

Acetic acid is used in the laboratory and in industry wherever a weak acid is needed. A strong base spilled on a woolen suit should be neutralized with acetic acid.

EXERCISES

1. What is the difference between an organic acid and an inorganic acid? List the names and formulas of three of each type.

2. What name is applied to the type of acid which contains only one other element besides hydrogen?

3. How do we name specific acids of the type mentioned in Exercise 2?

4. Define an acid.

5. Write the names and formulas for four ternary acids.

6. How are ternary acids named?

7. Explain why the valence of sulfur is 6 in H_2SO_4.

8. What are some common uses of sulfuric acid?

9. List five substances made by the use of sulfuric acid and state how each affects your life.

10. Explain how nitric acid may be considered the destroyer and the preserver of mankind.

11. Explain how it is possible for a person to drink large quantities of carbonic acid without harm.

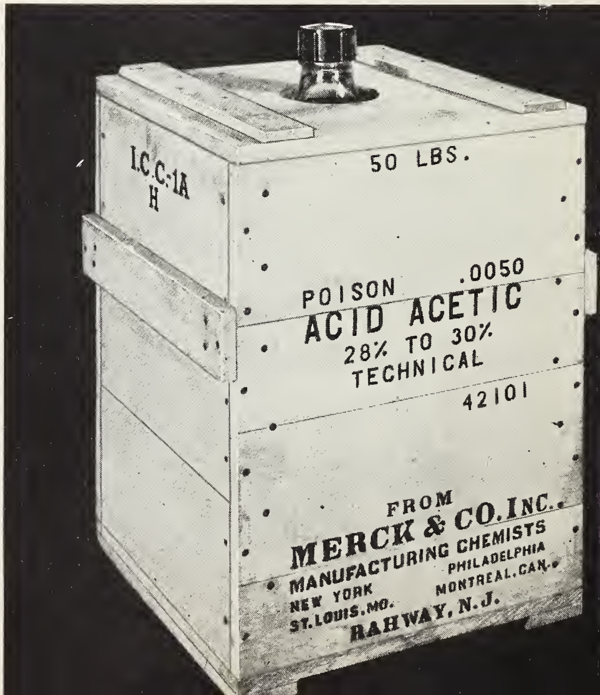
12. How is carbonic acid formed?

13. Write the word equation and the formula equation for the production of acetic acid.

Problem 3. How are acids prepared?

By metathesis. Many acids are made by metathesis. You wrote many equations involving this method in the unit on equation-writing. This is a general procedure; so its principles should be thoroughly understood. Concentrated sulfuric acid is a substance always used to produce the hydrogen ion of the acid that is desired. The negative ion is obtained from the cheapest salt which contains the desired negative ion. The salt and the sulfuric acid are mixed in retorts, and the contents are heated to the boiling point of the acid which is being made. Sulfuric acid has a boiling point of 335° C, which is relatively high, much higher than the boiling

Acids are often shipped to laboratories in large glass bottles called carboys



points of most other acids. For example, the boiling point of hydrochloric acid is 110° C, and the boiling point of nitric acid is 110°–120° C. Thus the acid that is desired can be driven off to be condensed or dissolved in water.

Much of the HCl (hydrochloric acid) of industry and commerce is prepared in the manner described above. Ordinary table salt furnishes the chloride ion (Cl^-), while moderately concentrated H_2SO_4 furnishes the hydrogen ion. The two equations following represent the way that this acid is produced from sulfuric acid:

$$NaCl + H_2SO_4 \longrightarrow NaHSO_4 + HCl\uparrow$$

$$NaHSO_4 + NaCl\text{ (excess)} \longrightarrow Na_2SO_4 + HCl\uparrow$$

The hydrogen chloride gas is passed into water, producing hydrochloric acid.

By the same method much nitric acid is produced. Sodium nitrate is used as the salt to furnish the NO_3^- ion:

$$NaNO_3 + H_2SO_4 \longrightarrow NaHSO_4 + HNO_3$$

By action of the anhydride of some acid upon water. The word *anhydride* comes from a Greek word meaning "without water." An anhydride is an oxide which, when added to water, produces an acid or a hydroxide. Nonmetallic oxides are the acid-producing anhydrides and are called *acid anhydrides.* Many acids can be made by simply adding the correct acid anhydride to water. For example:

1. $SO_2 + H_2O \longrightarrow H_2SO_3$
2. $SO_3 + H_2O \longrightarrow H_2SO_4$
3. $N_2O_5 + H_2O \longrightarrow 2\ HNO_3$
4. $P_2O_5 + 3\ H_2O \longrightarrow 2\ H_3PO_4$

EXERCISES

1. What is the name of the acid anhydride in each of the reactions above?

2. What is the name of each of the acids produced?

3. Write a paragraph on the subject "Sulfuric Acid Is the King of All Chemicals."

4. Write the equations for the production of citric, phosphoric, and hydrofluoric acids, assuming that you obtain the acids from the sodium salt containing the desired ions.

5. What are the two general methods of preparing acids? Illustrate each method.

6. Explain fully the process of preparing an acid by metathesis.

Problem 4. What are hydroxides?

Hydroxides, the chemical opposites of acids. The second class of inorganic compounds which go to make up the world of matter is called hydroxides. The word *base* is also commonly applied to these compounds. The strongest and most active of the hydroxides are called lyes or caustics.

Hydroxides, or bases, play a very important part in our everyday activities. We take some of them internally as medicines, and we use them in cleaning

Well-Known Hydroxides

Chemical Name	Formula	Common Name	Solubility; Ionization
Active Bases			
1. Sodium hydroxide	$NaOH$	Lye, or caustic soda	Very soluble; ionizes to a high degree
2. Potassium hydroxide	KOH	Potash, lye, or caustic potash	
Moderately Active			
3. Ammonium hydroxide	NH_4OH	Household ammonia; aqua ammonia	Partially soluble; ionizes slightly
4. Calcium hydroxide	$Ca(OH)_2$	Slaked lime; solution in H_2O is called limewater	
5. Magnesium hydroxide	$Mg(OH)_2$	Milk of magnesia; magnesia	
6. Barium hydroxide	$Ba(OH)_2$	None	
Slightly Active			
7. Aluminum hydroxide	$Al(OH)_3$	None	Very slightly soluble; furnishes few OH ions
8. Zinc hydroxide	$Zn(OH)_2$	None	
9. Ferrous hydroxide	$Fe(OH)_2$	None	
10. Ferric hydroxide	$Fe(OH)_3$	None	
11. Cupric hydroxide	$Cu(OH)_2$	None	

and washing. In nature, in factories, and in homes, bases are used to neutralize acids.

Hydroxides furnish hydroxyl ions. We have learned that an acid is a substance that furnishes hydrogen ions when dissolved in water. In a similar manner, it has been proved that a base is a substance which, when dissolved in water, will furnish hydroxyl, or hydroxide, ions (OH) as the only negative ions present. The positive ion of every base is a metallic ion or, in the case of ammonium hydroxide, a group of atoms (NH_4) which act as a metal. Thus you can see that a base is a substance made up of a metallic ion combined with the hydroxide ion.

Most hydroxides are insoluble. However, the soluble bases are among the world's most important compounds. Some of the most important soluble hydroxides are those of sodium, potassium, calcium, and ammonium. Hydroxides of nearly all the metals are possible. In the table at the foot of page 101 you will find a list of the most common hydroxides with their formulas, common names, solubilities, and extent of ionization.

EXERCISES

1. What is a hydroxide?
2. What are some common soluble hydroxides?
3. How does the number of soluble hydroxides compare with the number of those which are insoluble?
4. Give the chemical and the common names for the hydroxides which are used in the home.

Problem 5. What are the general properties of bases?

Characteristics of bases. All bases, or hydroxides, show certain characteristics or properties by means of which we can identify them.

1. All bases, or hydroxides, contain the hydroxyl ion as the only negative ion in the molecule.

2. All soluble bases affect indicators in the same manner. Many of the indicators used to show the presence of an acid can also be used to show the presence of a base. However, bases affect these indicators by producing a different color from that of acids. Bases turn red litmus blue in color, whereas acids turn the blue litmus back to red. Bases cause phenolphthalein to turn a deep-red color. Congo red, a dye obtained from coal tar, will turn to a scarlet color in the presence of bases, while in the presence of acids it will turn to a blue color. The color change of the indicator is caused by the OH^- ion of the base.

3. Most bases have a bitter taste. The strong bases must be very dilute to be safely put in the mouth because in concentrated form they attack and dissolve human tissue. The bitter taste of bases is much less characteristic than the sour taste of acids.

4. Bases act on acids. We have already learned that bases neutralize acids. This is due to the interaction between the OH^- ion of the base and the H^+ ion of the acid. A few equations will show this type of reaction. For example:

$$NaOH + HCl \longrightarrow HOH + NaCl$$

$$Ca(OH)_2 + H_2SO_4 \longrightarrow 2\ HOH + CaSO_4\downarrow$$

In the reactions above, the characteristic properties of the H and OH ions have been neutralized by each other. This can easily be demonstrated in the laboratory. If you add the proper amount of HCl solution to a beaker containing a solution of NaOH with a drop of phenolphthalein in it, the red color due to the indicator will disappear and the solution will become colorless. This shows that the OH ions of the base have all been counteracted by the H^+ ions of the acid. Other indicators can be used similarly. If the solution is tasted after the proper amounts of acid and base have been added to each other, it will be noticed that it does not have either the sour taste of an acid or the bitter taste of a base. Instead it tastes salty.

This phenomenon makes it quite evident that the properties which make a base basic, and similarly those that make an acid acidic, are due respectively to the presence of the negative OH^- ions and the positive H^+ ions. This process of forming water when a base unites with an acid is called *neutralization.*

Applications of neutralization. The process of neutralization is very important and is applied to our lives in many ways. We sometimes drink milk-of-magnesia solution (magnesium hydroxide, $Mg(OH)_2$) to neutralize excess acidity of the stomach. The magnesium hydroxide furnishes hydroxyl ions, which neutralize the excess acidity of the stomach. This substance or similar alkalizers should be used sparingly, as too much of such a substance keeps the hydrochloric acid in the stomach from serving its proper functions. Common advertisements of stomach powders, tooth pastes, and similar proprietary preparations tell us that we should use such preparations to neutralize acidity or hyperacidity. Such statements are very much overworked. The stomach is naturally acid, and hyperacidity in most people does not exist to any unnatural or alarming extent. When needed, reliable remedies will be prescribed by competent physicians. Do not be misled by scientific-sounding statements read in newspapers and magazines and heard over the radio. Too often the products so advertised are useless and worthless.

In the production of gasoline, sulfuric acid is used in the purification process. Any excess acid must be removed because of its corrosive effect upon the motor. The base sodium hydroxide is used as a neutralizing agent.

Since dilute ammonium hydroxide is a weak base, it is often used to neutralize acids spilled on clothing or on the body. The ammonia gas from the ammonium hydroxide may be inhaled to counteract the fumes of poisonous acid gases which may have been accidentally breathed.

EXERCISES

1. Would it be harmful to drink concentrated hydrochloric acid or sodium hydroxide solution? Why? If these two were mixed together in exactly the correct proportions, could you then drink the solution? Why? What would be the chemical names for the substances formed?

2. Why should you use ammonium hydroxide instead of sodium hydroxide to neutralize acid spilled on your clothing?

3. Why is limewater (dilute solution of $Ca(OH)_2$) given to babies?

Some common bases — lime, ammonia, magnesia, lye

Ewing Galloway

The girl accidentally spilled some lye on her dress. Why is she dipping the material in vinegar ?

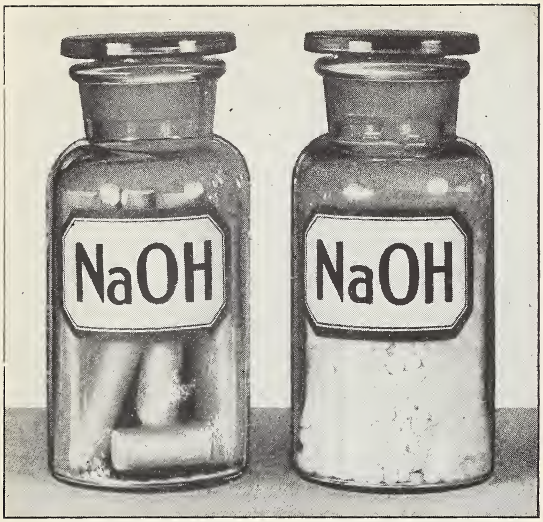
Problem 6. What should we know about some of the common bases?

Common lye. Sodium hydroxide (NaOH) is most generally called lye. It is the most widely known and used base. Compounds made from it are so common that you will be using sodium hydroxide to make them all through your high-school chemistry course. Sodium hydroxide is made by passing electricity through a common table salt (NaCl) solution. This base has a very great commercial value because it is used in so many industries. The soap industry uses large quantities of this substance.

Soap is made from sodium hydroxide or potassium hydroxide by "cooking" either of these materials with fat. The equation for this reaction is as follows:

$$3\,\underset{\text{lye}}{\mathrm{NaOH}} \underset{+}{+} \underset{\text{fat}}{\mathrm{C_3H_5(C_{17}H_{35}COO)_3}}$$

$$\underset{\longrightarrow}{\longrightarrow} 3\,\underset{\text{soap}}{\mathrm{NaC_{17}H_{35}COO}} \underset{+}{+} \underset{\text{glycerin}}{\mathrm{C_3H_5(OH)_3}}$$



Sodium hydroxide is sold to laboratories in the form of sticks or pellets

Sodium hydroxide is called caustic soda because of its corrosive action on animal tissue. It also affects plant fibers, such as cotton and linen, and is used in the textile industry to "mercerize" cotton and to make rayon. Lye is a solid at ordinary temperatures and is purchased in stick, flake, or pellet form. You will use a solution of this solid in the laboratory.

In the commercial canning of such fruits as peaches and apricots, common lye is used to remove the peel. Corn is soaked in lye to make hominy. In each case the excess lye is removed by careful washing.

Caustic potash (KOH). This base is very similar to sodium hydroxide and exhibits the same properties. It is slightly stronger than sodium hydroxide, and its action is therefore more "caustic." It is used to make soft soap, while sodium hydroxide is used to make hard soap. Both the hydroxides are deliquescent; that is, they absorb moisture from the air, become moist, and dissolve in the solution. You may observe this property by placing a few pellets of either of these hydroxides on a watch glass, and in a short time you will notice that they have become moist and pasty. This property makes them valuable as dehydrators.

Sodium hydroxide and potassium hydroxide both ionize well when dissolved in water and are classed as strong bases. A hydroxide which does not ionize well or is so insoluble that it furnishes few OH^- ions per unit volume is known as a weak hydroxide.

Hydrated, or slaked, lime ($Ca(OH)_2$). This is a very important hydroxide and is used widely because it is cheap as compared with sodium and potassium hydroxide. It is made from limestone ($CaCO_3$), which is abundant in nature. Calcium hydroxide is called slaked or hydrated lime because it is simply lime (CaO) plus water. All bases, except ammonium hydroxide, may be considered as metallic oxides combined chemically with water.

$$CaO + H_2O \longrightarrow Ca(OH)_2$$

Slaked lime is used wherever a cheap source of the OH^- ion is needed. For example, it is used in the liming of farm lands to neutralize so-called sour soils. Calcium hydroxide does not dissolve well in water. However, the part that does dissolve ionizes well. A weak solution is given internally to infants and invalids to neutralize sourness of the stomach. The acid in the stomach is hydrochloric. Write the equation for the neutralization that takes place when calcium hydroxide is administered internally. Name the products.

Ammonium hydroxide (NH_4OH). This substance is commonly called household ammonia, ammonia water, or aqua ammonia. It is produced by the action of ammonia gas (NH_3) upon water, thus:

$$NH_3 + HOH \rightleftarrows NH_4OH$$

Look carefully at the equation above, and notice that there are two arrows, one pointing right and the other left. This indicates that the compound decomposes readily and that the reaction is reversible. There are many reversible reactions in chemistry, and you will read of them many times in this book. You can easily demonstrate to yourself that NH_4OH decomposes by smelling a bottle of this substance. If a bottle of it is left unstoppered for any length of time, the reaction will go completely to the left, and the bottle will contain only water. The ammonia gas (NH_3) has escaped. Great quantities of NH_3 can be made to dissolve in H_2O, with the production of what is known as concentrated ammonium hydroxide. It is usually purchased in this form. This base ionizes as follows:

$$NH_4OH \rightleftarrows (NH_4)^+ \text{ and } (OH)^-$$

Thus the NH_4 radical acts just as a metal does in the other hydroxides. This accounts for the *ium* ending, corresponding to that given to the names of certain metals.

Ammonium hydroxide is widely used as a cleanser and as a weak neutralizing agent. Why is ammonium hydroxide solution used to clean windows? (HINT: Remember that ammonium hydroxide is a volatile hydroxide.)

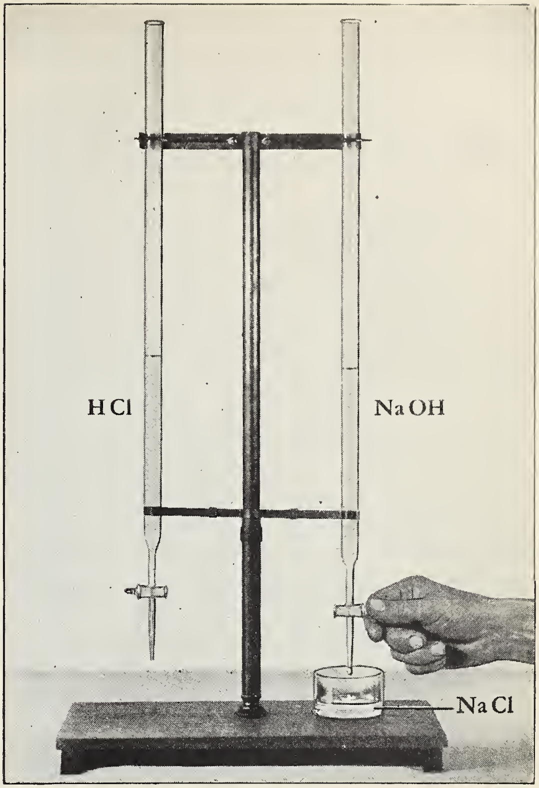
EXERCISES

1. Describe the process and write the word equation for the preparation of soap.
2. What are some common uses of lye?
3. How is lye prepared?
4. What is meant by the term *deliquescent*?
5. How does potassium hydroxide differ from sodium hydroxide?
6. Why is slaked lime more widely used than other hydroxides?
7. How is slaked lime made?
8. What are some of the common uses of calcium hydroxide?
9. How is ammonium hydroxide made? Write the equation.
10. What is a reversible reaction?

Problem 7. What are salts, and why are they important to us?

Salts, the largest group of inorganic compounds. The word *salt* has been used many times in this book, and you no doubt heard the word before you came into the chemistry classroom. You have probably applied the word to only one compound, ordinary table salt, or sodium chloride. However, salt is also a general term that is used to describe a large class of compounds. There are literally thousands of salts. Though they all possess certain characteristics in common, you must not form the conclusion that they are all like ordinary table salt. Although acids and bases are important to our lives, salts are more important. Our health and vitality are dependent upon our having sufficient mineral salts in our diet. Our bones are composed of salts, and minerals of other kinds are found in other parts of our body.

We learned that acids possess certain properties in common, such as a sour taste and a certain action on litmus. Also, we have learned that inorganic bases, or hydroxides, possess certain other properties, such as bitterness to the taste and an action on indicators opposite to that of acids. Moreover, we have learned that acids neutralize bases. The common properties of these two classes of compounds and the fact that they neutralize each other are due to the presence of the common ion H^+ in the acids and the common ion OH^- in the bases. Salts, which are formed when an acid neutralizes a base, do not contain a common ion; therefore they differ widely in their properties. Some salts taste sour, some alkaline, and some salty. They affect litmus and other indicators in various ways. Some are extremely soluble in water, while many are only very slightly soluble or are insoluble.



When a solution of sodium hydroxide is exactly neutralized by the addition of dilute hydrochloric acid, a neutral salt solution is formed. The graduated glass tubes, called burettes, are used to measure accurately the amounts of each solution used in the neutralization process

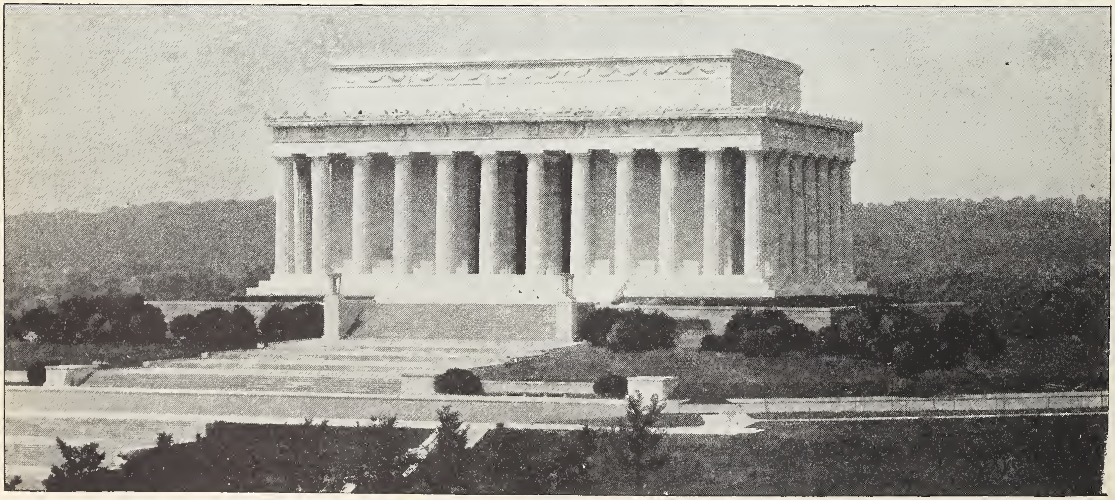
A salt is a compound which contains a positive metallic ion other than the hydrogen ion and a negative nonmetallic ion other than the hydroxyl ion.

Many salts are found in the earth's crust. Indeed, a large percentage of all minerals are salts. Only those minerals that are oxides and elements are not salts.

The salts of the earth. The story of minerals and salts is a very fascinating one but too long to be completely told here. Many salts are soluble and thus find themselves dissolved in the surface waters. Being soluble, many of the needed ones are taken up by plants. From this temporary resting place they go either into the make-up of animals as foodstuffs or into the soil again for other plants to use. Much of the soluble salt material flows away to the sea; so it is not surprising to find a little of many kinds of salt in sea water. Sea water is from 3 per cent to 3.6 per cent solid material, and chemical analysis shows that 80 per cent of this amount is common table salt (NaCl). The other 20 per cent is composed of a little of everything that there is on this earth, chiefly other soluble salts. To visualize fully the magnitude of the quantities of salt that there are in the sea, remember that the ocean covers three quarters of the earth's surface to an average depth of three miles. If all this water were evaporated, we should have approximately 6,000,000 cubic miles of solid salt. This is enough to furnish 18,000,000,000,000 tons of chlorine, if we consider that probably 90 per cent of the salts are chlorides and that chlorine constitutes approximately 60 per cent of common table salt. Many soluble salts are still locked up in parts of the earth where there is little rainfall, or where the deposits are so thick or so well protected that complete solution has not occurred.

There are also large amounts of insoluble salts. No one has attempted to compute the vast quantities of these materials that go to make up the earth's crust. Man has had to find ways to unlock some of the needed salts that are bound up in these insoluble compounds. Interesting examples are the potassium compounds. The world's supply of the soluble salts is very limited, but chemical engineers have found them in abundance in the insoluble mineral deposits called sylvite, polyhalite, and alunite. Chemists have found ways to extract the potash from these substances profitably, and now the United States exports potassium compounds, whereas formerly she imported them. Potassium is needed chiefly to replenish soils with that element as a fertilizer.

Houses are built of salts. Insoluble salt particles cemented together have long been used as building materials. Clay, from which bricks are made, is a



The Lincoln Memorial in Washington, D.C., is made of the insoluble salts white marble and limestone salt called hydrogen aluminum silicate. Marble and limestone are largely the salt calcium carbonate. The plaster on the walls of our homes is largely this same compound.

Ores that are insoluble salts. Many ores found in nature are insoluble salts, and we are able to obtain valuable metals from such salts. For example, lead is obtained from lead sulfide (PbS), which as an ore is called galena; zinc is obtained from zinc sulfide (ZnS), or zinc blende; mercury, from mercuric sulfide (HgS), or cinnabar; and iron, from iron carbonate ($FeCO_3$), or siderite.

EXERCISES

1. How are salts formed?
2. Define a salt.
3. Why does sea water contain many salts in solution?
4. Name and give the formula for some commonly used insoluble salts.

Problem 8. How are salts formed?

Three principal methods of preparing salts. You have already discovered that many salts occur in nature ready for man's use. However, many salts are found only in small quantities, while others which are necessary for our use do not exist in nature. Through experimentation we have learned how to prepare many of these salts. It is desirable for you to learn about the most common methods used in the preparation of salts.

1. *Salts are formed by neutralization.* When an acid is neutralized by a base, the products are always a salt and water. Any salt may be prepared in this manner by selecting a base that contains the desired metallic ion and an acid that contains the desired nonmetallic ion. Thus, if we wish to prepare potassium nitrate (KNO_3) in the laboratory, the metallic K ion is obtained from potassium hydroxide (KOH), and the nonmetallic NO_3 ion is obtained from nitric acid (HNO_3):

$$KOH + HNO_3 \longrightarrow KNO_3 + HOH$$

2. *Salts are formed when a metal reacts with an acid.* The hydrogen of the acid is released as a gas if the metal is more active chemically than hydrogen. If the metal is less active than hydrogen and the acid is an oxidizing acid, then water, a salt, and some gas are produced. Examples of salt formation where the metals are more active than hydrogen are

$$Zn + 2\ HCl \longrightarrow ZnCl_2 + H_2\uparrow$$
$$Fe + H_2SO_4 \longrightarrow FeSO_4 + H_2\uparrow$$

Examples of salts formed by oxidizing acids on metals less active than hydrogen are

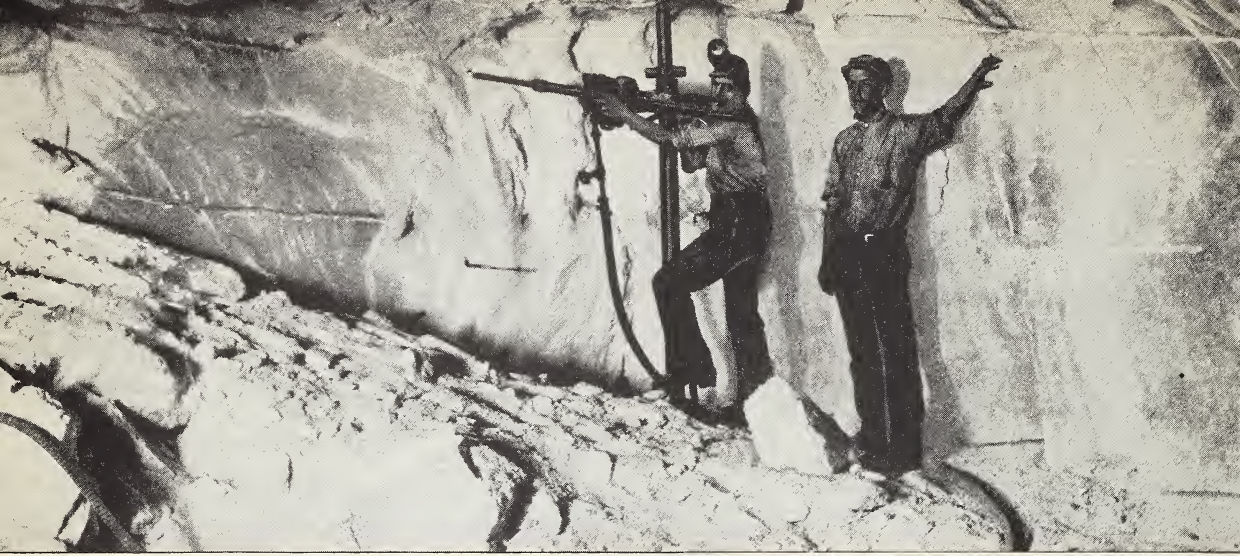
$$3\ Ag + 4\ HNO_3 \longrightarrow 3\ AgNO_3 + 2\ H_2O + NO\uparrow$$

Actually very little nitric oxide gas (NO) is evolved. Usually the reddish-brown nitrogen dioxide (NO_2) is evolved because the NO unites with the O_2 of the air:

$$2\ NO + O_2 \longrightarrow 2\ NO_2\uparrow$$
$$Cu + 2\ H_2SO_4 \longrightarrow CuSO_4 + 2\ H_2O + SO_2\uparrow$$

"Harvesting" solar salt with the aid of machinery. In the background a portable elevator is piling up a mountain of salt

Morton Salt Company



Morton Salt Company

Drilling holes preparatory to blasting out solid rock salt in a Texas salt mine

3. *Salts are formed from other salts.* A salt may also be produced by the interaction between two salts when they are dissolved in water. For example, suppose we wished to prepare some barium sulfate ($BaSO_4$). We would put a water solution of barium nitrate with one of sodium sulfate and obtain barium sulfate as a precipitate, with sodium nitrate remaining in solution:

$$Ba(NO_3)_2 + Na_2SO_4 \longrightarrow \underset{\text{white}}{BaSO_4}\downarrow + 2\,NaNO_3$$

When salts are prepared in this manner, the cheapest sources of the desired ions are always used. Also, such salts must be used that they will form as a product the salt desired in insoluble form or the undesired salt in the insoluble form. This must be watched, or else separation of the two products will be extremely difficult or impossible. In the example shown above, the $BaSO_4$ would be filtered, washed with pure H_2O, dried, and then be ready for use.

As an example of a second type of reaction, let us make the salt KNO_3. We could put a solution of potassium chromate with a solution of lead nitrate and obtain, as products, insoluble lead chromate and soluble potassium nitrate:

$$K_2CrO_4 + Pb(NO_3)_2 \longrightarrow 2\,KNO_3 + \underset{\text{yellow}}{PbCrO_4}\downarrow$$

The potassium nitrate would be obtained by filtering out the insoluble $PbCrO_4$ and evaporating the filtrate to dryness. The residue obtained from the filtrate would be KNO_3.

EXERCISES

1. Name and describe the three methods of preparing salts.

2. Write balanced equations for the preparation of the following salts:

a. Ammonium carbonate from ammonium hydroxide and carbonic acid.

b. Sodium nitrate from silver nitrate and sodium chloride.

c. Aluminum sulfate from aluminum and sulfuric acid.

d. Calcium sulfate from calcium nitrate and potassium sulfate.

Problem 9. How are salts named, and how are they classified?

Salts take the names of positive and negative ions. Salts are named according to a very simple rule. There are two parts to the name of every salt: first, the name of the positive ion, which is the name of the metal, and second, the name of the negative ion, which is related to the name of the acid from which the salt is derived. If you have memorized the names of the positive and negative ions, you will experience no difficulty in naming salts.

Since salts are produced by the neutralization of a base by an acid, we sometimes think of the name of the salt as being derived from the name of the acid from which it is made.

Sulfates are salts of sulfuric acid.
Sulfites are salts of sulfurous acid.
Sulfides are salts of hydrosulfuric acid.
Phosphates are salts of phosphoric acid.
Nitrates are salts of nitric acid.
Nitrites are salts of nitrous acid.
Carbonates are salts of carbonic acid.
Chlorides are salts of hydrochloric acid.
Acetates are salts of acetic acid.

In general, the names of salts of *ic*-ending acids end in *ate*; the names of salts of *ous*-ending acids end in *ite*; and the names of salts of *hydro–ic* acids end in *ide*.

Hydrates—salts containing water of hydration, or crystallization. Water unites with many salts to form what are commonly called hydrates. The water that is combined with the salt molecule is in relatively loose chemical union and may be easily driven off by heat. There are many common salts which contain water of hydration. An example is crystalline copper sulfate (blue vitriol), which contains five molecules of water of hydration united loosely with every molecule of copper sulfate. The formula for this compound is $CuSO_4 \cdot 5\ H_2O$. The dot in this formula indicates the loose chemical union between the two different kinds of molecules. Since many crystalline compounds contain water of hydration, the term *water of crystallization* is sometimes used.

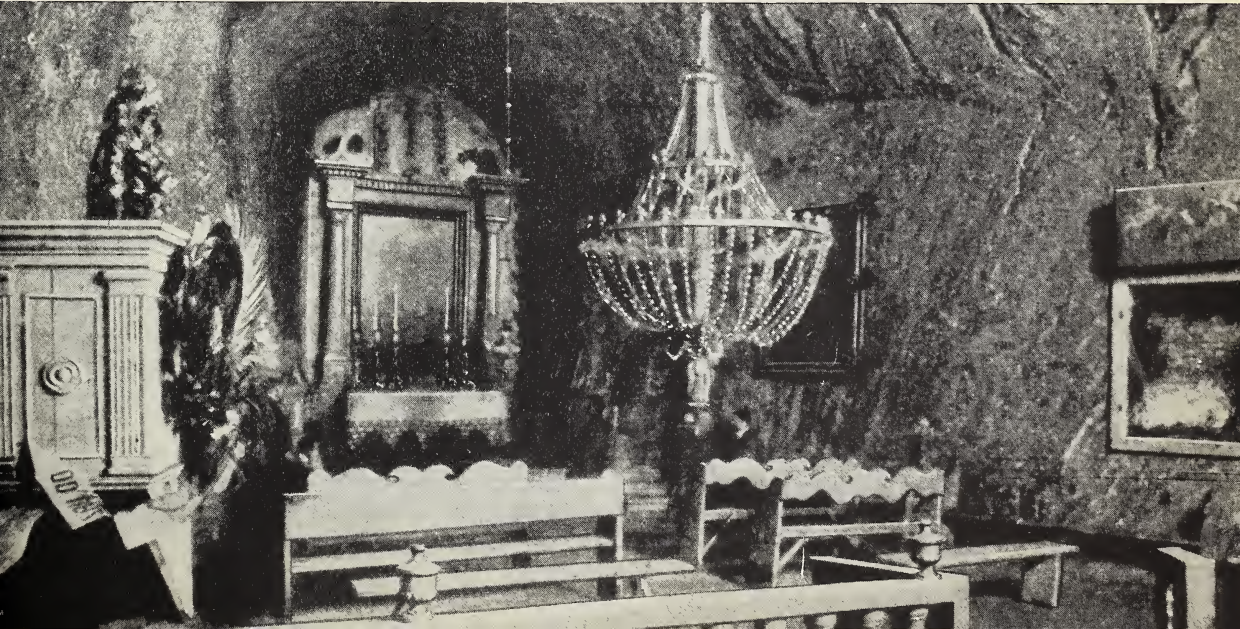
When the water is driven off from such a salt, the anhydrous, or dehydrated, form of the salt is obtained. Some salts which contain water of hydration lose this combined water when exposed to air and are said to be *efflorescent*. An example is washing soda, which in the crystalline form has the formula $Na_2CO_3 \cdot 10H_2O$, but when exposed to air for some time loses its water of hydration and has the formula Na_2CO_3.

Normal, acidic, basic, and double salts. Most salts with which you will work are called *normal salts*. A normal salt is one that contains just the metallic ion and the nonmetallic ion, no hydrogen or hydroxyl ions being present. Chemically, normal salts are produced when all the hydrogen of an acid has been replaced by a metal. Ordinary table salt is a normal salt. Sometimes not all the hydrogen is replaced, but some of it remains as a part of the salt. This type of reaction produces a kind of salt called an *acid salt*. For example, if sodium hydroxide is neutralized by dilute sulfuric acid, the salt produced is normal sodium sulfate, as shown by this equation:

$$2\ NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + 2\ H_2O$$

A chapel hewn out of solid salt 200 feet down in a Polish salt mine. Its once snowy-white walls have been blackened by the burning of thousands of candles. The prisms on the chandelier are crystals of pure salt

Morton Salt Company



However, if the acid is partially concentrated, the salt produced is sodium acid sulfate, according to this equation:

$$NaOH + H_2SO_4 \longrightarrow NaHSO_4 + H_2O$$

Salts like this one are also called bisalts or hydrogen salts. $NaHSO_4$ is called sodium bisulfate, sodium acid sulfate, or sodium hydrogen sulfate. These names are all applied to this compound, and other acid salts are named similarly. There can be acid salts produced for every acid that has more than one hydrogen atom in its molecule. Most acid salts are soluble. A common one used in the home is sodium bicarbonate ($NaHCO_3$), common baking soda.

There is a third group of salts known as *basic salts.* These salts have the OH^- radical in their molecules. They are formed when some of the OH^+ ions of a base are neutralized by the H^+ ions of the acid. For example, if bismuth hydroxide is neutralized by hydrochloric acid, the salt called basic bismuth chloride is formed:

$$Bi(OH)_3 + HCl \longrightarrow Bi(OH)_2Cl + HOH$$

Basic salts occur freely in nature. Most of them are insoluble. Some valuable ores are basic salts. Examples of basic salts are white lead, a paint pigment which has the formula $PbCO_3 \cdot Pb(OH)_2$ or $Pb_2(OH)_2CO_3$, and malachite, which is a basic copper carbonate, with the formula $CuCO_3 \cdot Cu(OH)_2$.

A fourth group of salts is called *double salts.* They consist of two metallic ions, other than hydrogen, with a nonmetallic ion. Examples are alum, $NaAl(SO_4)_2 \cdot 12\,H_2O$ or $KAl(SO_4)_2 \cdot 12\,H_2O$, and Rochelle salt, $NaKC_4H_4O_6$. Write the chemical names of these two double salts.

Since salts differ so widely in their chemical make-up, it is plain why they do not all possess common properties, as do acids and bases.

There are still other salts from other acids that have not been mentioned. If you are planning to specialize in chemistry, it will be wise for you to look up these acids and their salts in some good reference book. The acids are those ternary acids in which the nonmetal has additional valences other than those required to produce the ordinary *ic* and *ous* acids. An example is chlorine. It forms perchloric acid ($HClO_4$) and hypochlorous acid ($HClO$), in addition to chloric acid ($HClO_3$) and chlorous acid ($HClO_2$). The salts from these acids are named as follows:

Perchloric acid produces perchlorate salts.
Chloric acid produces chlorate salts.
Chlorous acid produces chlorite salts.
Hypochlorous acid produces hypochlorite salts.

Name the acids and salts that are possible for the nonmetal iodine.

EXERCISES

1. Since there are as many salts for each acid as there are metals, it is readily seen that salts are numerous. A good way to get acquainted with them is to write all the salts that you can for each acid. As an aid in doing this, copy the following table and write the formulas for the salts indicated. Some of the compounds do not exist.

Metals	H_2SO_4		HNO_3	HCl	H_2SO_3	
	Normal Salt	*Acid Salt*	*Normal Salt*	*Normal Salt*	*Normal Salt*	*Acid Salt*
Na	Na_2SO_4	$NaHSO_4$	$NaNO_3$	$NaCl$	Na_2SO_3	$NaHSO_3$
K						
Mg						
Al						
Zn						
Fe^{++}						
Hg^+						
Fe^{+++}						
Hg^{++}						
Bi^{+++}						
Ag						

2. Write the names of the following salts: Na_3PO_4, K_2SO_3, $Ca(HCO_3)_2$, and ZnS.

3. Define *normal salt*, *acid salt*, *basic salt*, and *double salt.* Give examples of each class of salt.

Problem 10. What are the properties of salts?

The negative ion determines certain properties of salts. Sometimes salts are classified according to the negative ion. Thus some books will show all the properties of the sulfate salts, the nitrate salts, the chloride salts, etc. This is permissible because the same negative ion in a group of salts does impart to them similar properties. The property of solubility in water of salts is dependent somewhat upon the negative ion in the salts. The following generalizations apply to all the more common salts:

1. Nitrate and acetate salts are soluble.
2. Chloride salts are soluble except those of Ag, Hg, and Pb. ($PbCl_2$ is soluble in hot water.)
3. Sulfate salts are soluble except those of Pb, Ca, Ba, and Sr.
4. Carbonate, phosphate, silicate, and sulfide salts are insoluble, except those of Na, K, and NH_4.
5. In general, acid salts are more soluble than normal salts, and basic salts are less soluble than normal salts.

The solubility of salts may determine use. It is very important that the chemist and the industrialist know the solubility of the common salts. Many of the uses of salts depend upon their solubility or insolubility. For example, building materials, such as concrete, brick, and paint, which are to be exposed to weather must be insoluble in water.

Since nitrates provide plant food, they are usually found in fertilizers. Being soluble, the nitrates readily go into solution and are immediately available as plant food. There are usually more nitrate salts than any others on the shelves of the average high-school laboratory, because all nitrates are soluble.

The negative ion may determine use of salts. If you were asked to go to the laboratory stock room and make a solution containing the cobalt ion, it is probable that you would immediately select cobalt nitrate. You would do this because you know that all nitrate salts are soluble. Because of this property of solubility, regardless of the positive ion, more solutions of nitrate salts are used than of any other salt.

Some salts exhibit a strong power of oxidation because of the negative ion. Most common among the oxidizing salts are the nitrates, chlorates, perchlorates, and permanganates. The first of these are used in explosives to some extent because of this property.

Some salts are poisonous to living organisms because of the presence of certain negative ions. While many are injurious to some extent, the cyanides are the most deadly. Sodium fluoride is used as ant poison because of its negative ion.

The effectiveness of many drugs is measured by the negative ion present. Tannates are used for burns, bromides are used in sedatives, chlorates are used in cough medicines, and salicylates are used in aspirin.

The positive ion determines certain properties of salts. In addition to the negative-ion type of classification, some chemists classify salts according to the positive ion. Thus they group all sodium salts into one family, all copper salts into another, etc. This is justifiable, because the common metallic ion, which is present in a group of salts, does impart some common properties. For solubility, these two generalizations generally hold:

1. Na, K, and NH_4 salts are soluble in water.
2. The solubility of the other metallic-ion groups is dependent upon the negative ion.

All cupric salts in water solution have a blue color, which must be due to the copper ion. Cupric sulfate is a good insecticide because of the copper ion.

Most ferric salts, when dissolved in water, give the solution a reddish-brown color, which is due to the action of the ferric ion.

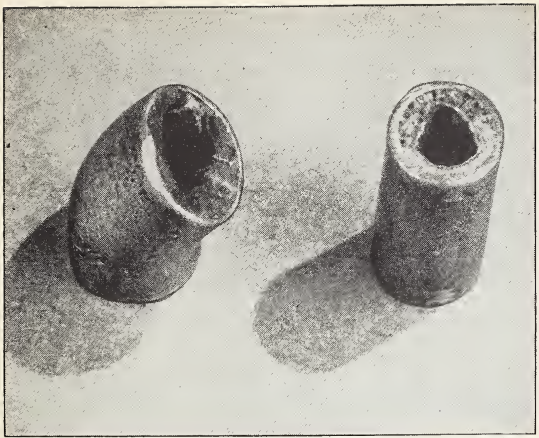
Mercury salts are poisonous because of the mercuric or mercurous ion. This is also true of many of the heavy metallic salts.

Many salts produce characteristic flame coloration when burned. This is due to the metallic ion. The following table shows the color imparted to a flame by certain metallic salts:

Salts of	Color of Flame Produced
Strontium	Red
Copper	Green
Barium	Olive green
Calcium	Orange
Lithium	Cerise
Potassium	Purple
Sodium	Golden yellow

Calcium and magnesium salts, when dissolved in water, produce a quality in the water called hardness. This is due to the presence of the calcium or magnesium ion, and is independent of the negative ions that may be combined with metals. Not all calcium and magnesium salts are soluble, and it must be remembered that only those which are soluble produce this effect.

The hydrolysis of salts. Some salts, when dissolved in water, produce substances and exhibit properties that you would not expect. This is because they unite with the positive H and the negative OH ions of water. For example, if $Al_2(SO_4)_3$ is dissolved in water, the solution will turn blue

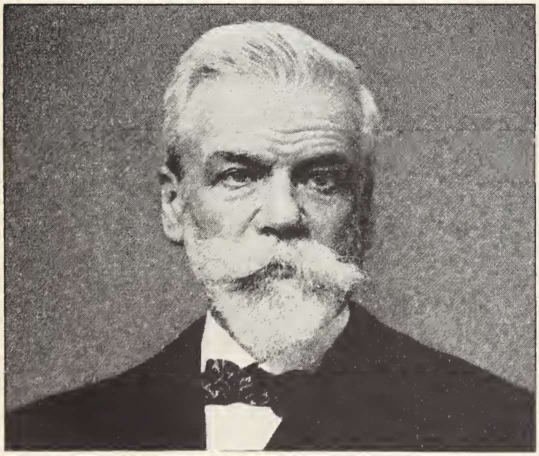


Ewing Galloway

Deposit of boiler scale caused by the minerals in hard water

litmus red. What has caused this change? There are no free H^+ ions in the aluminum sulfate or in the water, and yet the presence of H^+ ions is the cause of the change in blue litmus. Chemists explain the phenomenon in this way: Water is very slightly ionized; about one out of 500 million molecules is dissociated, or broken apart. This is not enough ionization to make water a conductor of electricity; so it is called a nonelectrolyte. However, there is enough ionization to produce the change mentioned above with $Al_2(SO_4)_3$. Since water itself is neutral, the numbers of hydrogen and hydroxyl ions are equal. If any chemical action tends to reduce the number of one of these ions, the other ion will then be present in excess and will give its characteristic reaction to litmus or any other indicator.

Ernest Solvay (1838–1922), the famous Belgian chemist, who discovered the process of manufacturing sodium bicarbonate and sodium carbonate



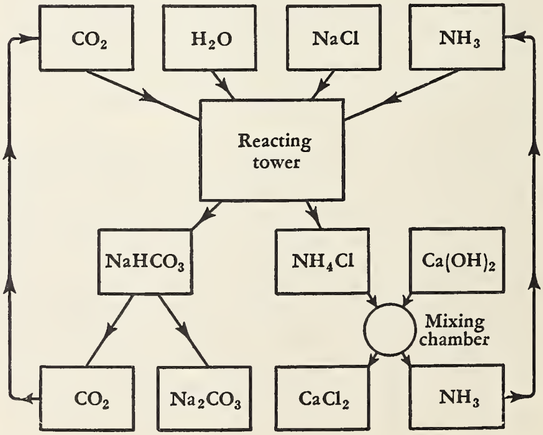
In the reaction between $Al_2(SO_4)_3$ and H_2O, very small amounts of sulfuric acid and aluminum hydroxide are formed because of the slight ionization of the water, thus:

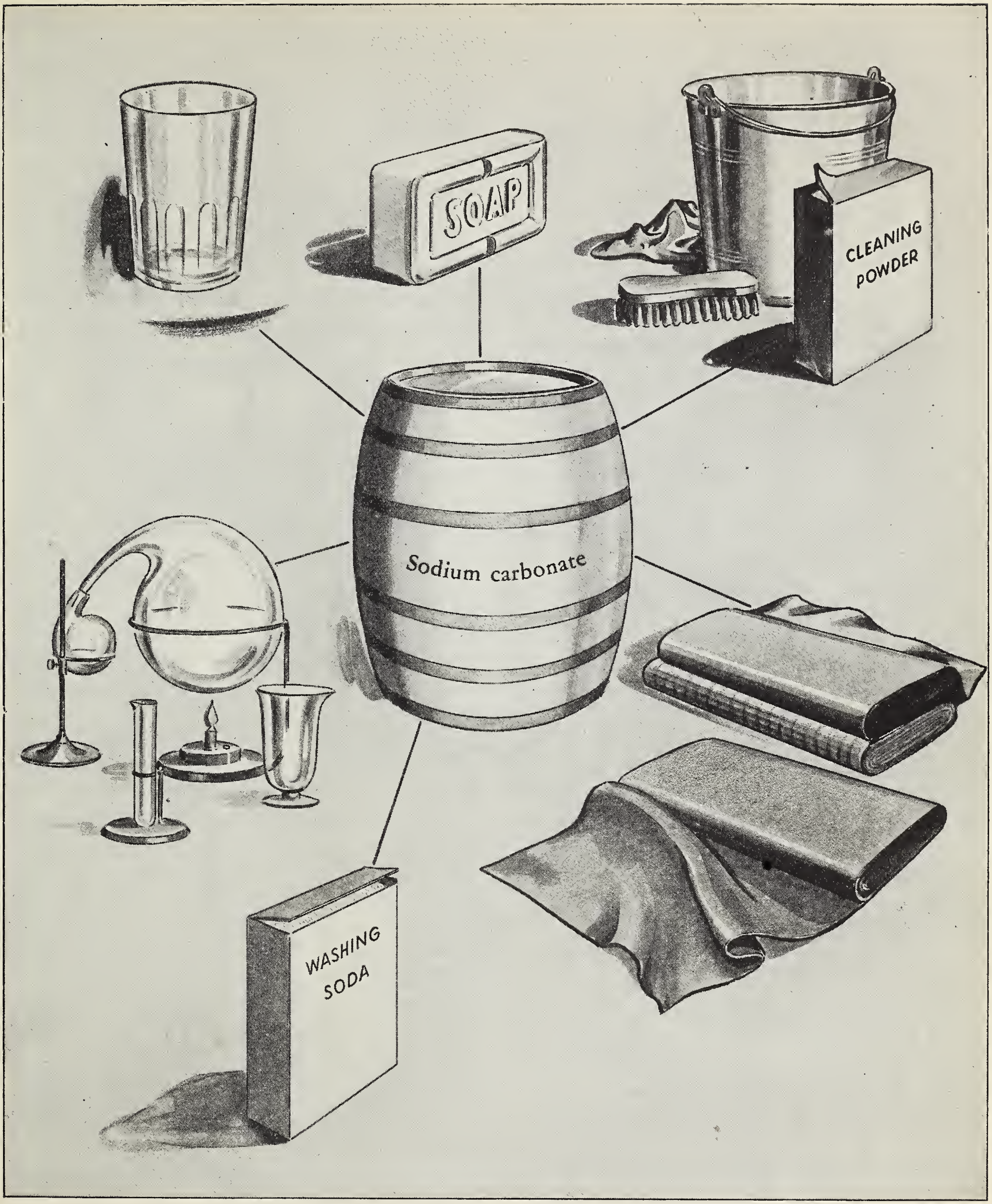
$$Al_2(SO_4)_3 + 6\,HOH \rightleftharpoons 2\,Al(OH)_3\downarrow + 3\,H_2SO_4$$

Now aluminum hydroxide is insoluble and ionizes but little, while sulfuric acid ionizes highly; therefore OH^- ions are taken out of solution, whereas H^+ ions remain. Therefore the solution shows an excess of H^+ ions and is acidic. This reaction never produces a large excess of H^+ ions, because just as soon as the concentration of the sulfuric acid increases to a certain point, it then acts upon the aluminum hydroxide to form aluminum sulfate and water. Thus this particular reaction is a reversible reaction. This compound,

This diagram shows the Solvay process for manufacturing sodium bicarbonate and sodium carbonate. In this process the salt is dissolved in water, and then, in the reaction tower, the salt solution reacts with ammonia and carbon dioxide to form sodium bicarbonate. The following reactions take place in the process:

$$CO_2 + NH_3 + H_2O \longrightarrow NH_4HCO_3$$
$$NH_4HCO_3 + NaCl \longrightarrow NH_4Cl + NaHCO_3$$
$$2\,NaHCO_3 + \text{heat} \longrightarrow Na_2CO_3 + H_2O + CO_2$$





Some of the many products which require sodium carbonate in their manufacture

$Al_2(SO_4)_3$, is used in water purification because of the reaction above. $NaAl(SO_4)_2$ is widely used in baking powders because of hydrolysis. The use of $Al_2(SO_4)_3$ and $NaAl(SO_4)_2$ for the purposes mentioned will be explained later.

The salt sodium carbonate similarly hydrolyzes, or reacts with water. The solution, however, shows basic properties. A glance at the equation for this reaction shows why this is true:

$$Na_2CO_3 + 2\ HOH \rightleftharpoons 2\ NaOH + H_2CO_3$$

Here we notice that the highly ionized base sodium hydroxide is formed, and the slightly ionized carbonic acid is produced at the same time. Therefore we should expect that the OH^- ions would be in excess. Testing this solution with red litmus verifies our assumption, since the red litmus immediately turns blue. As in the former example, the strength of the NaOH would never become great, because it would react with the H_2CO_3 after it had reached a certain concentration, and reverse the reaction.

There is always enough of the NaOH present when the salt Na_2CO_3 is dissolved in water to make it a valuable substance in industry and in the home as a cleaning agent. It is a component of washing powders, powdered soaps, etc. It is commonly called sal soda or washing soda. It is generally sold in the crystalline form, and has the formula $Na_2CO_3 \cdot 10\ H_2O$. It is much more economical to buy it in the anhydrous, or dehydrated, form with the formula simply Na_2CO_3. In the form of the hydrate it is approximately 70 per cent water.

When the salt sodium bicarbonate ($NaHCO_3$) is put with water, a reaction similar to that of Na_2CO_3 with water takes place:

$$NaHCO_3 + HOH \rightleftharpoons NaOH + H_2CO_3$$

This substance furnishes only one molecule of NaOH per molecule of $NaHCO_3$ that is dissolved, whereas the Na_2CO_3 produces two molecules of NaOH. Therefore the sodium bicarbonate gives a much weaker basic reaction than the normal sodium carbonate. Sodium bicarbonate is commonly called baking soda, and is a constituent of all baking powders. We use baking soda to relieve the itching of bee stings and ant bites because of its mild basic reaction in neutralizing the acid of the sting.

When a salt unites with water to form an acid and a base, one of which is stronger, or more highly ionized, than the other, the process is called hydrolysis. There are many examples other than those already mentioned, although not all salts hydrolyze. Sodium chloride does not hydrolyze, because the acid HCl, which is formed, is just as strong as the base, NaOH, which is formed at the same time.

The term *hydrolysis* is used in chemistry to mean the union of water with another substance to produce a different substance. For example, water will unite with starch to form the sugar glucose, as shown in the following equation:

$$\underset{\text{starch}}{C_6H_{10}O_5} + \underset{\text{water}}{HOH} \longrightarrow \underset{\text{glucose}}{C_6H_{12}O_6}$$

The individual uses and properties of many salts will be studied in some detail in other parts of this book, where situations are dealt with in which the salts vitally affect our living.

This discussion of salts can be closed by telling of an interesting demonstration. A chemist once displayed before an audience two poisonous compounds, sodium hydroxide and hydrochloric acid, in two separate containers. He explained that if either were taken internally, much pain and very serious injury to the mouth and intestinal tract would result. He then proceeded to pour the contents of sodium hydroxide into the beaker of hydrochloric acid and, after stirring, calmly drank the new compound that was produced. Some of the uninformed of his audience were horror-stricken, but, of course, he was uninjured because he was drinking merely a solution of ordinary table salt, NaCl. You must not try this unless your chemistry teacher helps you to figure exactly the correct amounts of each compound to use. An excess of either of the compounds would be dangerous to your health.

EXERCISES

1. How may the solubility of a salt be determined from the negative ion?
2. Give examples to show how the solubility of a salt may determine its use.
3. Give illustrations to show how the negative ion of a salt may determine its use.
4. How may the solubility of a salt be determined by the positive ion?

5. What uses of salts are due to their positive ions?
6. How may the positive ion of a salt be discovered by a flame test?
7. What is hydrolysis?
8. Explain by an equation how hydrolysis takes place.

Problem 11. What are oxides?

Oxides, the fourth class of inorganic compounds. An oxide is simple in composition. It is any element combined with oxygen, and there are many oxides because oxygen is so prevalent. Many oxides were formed in the early stages of the earth's formation, and therefore we find many ores that are principally oxides. Oxides are being formed constantly all about us. The oxidation of compounds and elements is never-ending; there will be oxides as long as there is oxygen. Since the supply of oxygen is continually being regenerated by plants and vegetation, there must always be oxides.

If a metal combines with oxygen, the product is a metallic oxide; and if a nonmetal unites with oxygen, the substance produced is a nonmetallic oxide. You should study the table at the bottom of this page to become acquainted with some of the most common metallic and nonmetallic oxides.

Metallic oxides. All metals except those that are very inactive, such as gold (Au) and platinum (Pt), form oxides. Metallic oxides are known as base-formers because when they unite with water, a hydroxide is produced. For example:

$$CaO + H_2O \longrightarrow Ca(OH)_2$$
$$K_2O + H_2O \longrightarrow 2\ KOH$$
$$Al_2O_3 + 3\ H_2O \longrightarrow 2\ Al(OH)_3$$

Metallic oxides are often called basic oxides or basic anhydrides.

Most of the iron which man uses in this machine age is obtained from iron oxides. After free iron is obtained from its oxides and made into machines, the processes of nature tend to change it back to iron oxide. Man spends millions of dollars annually to prevent the oxidation of metals such as iron by covering the surface of the metals with lacquers and paints.

Nonmetallic oxides. The nonmetallic oxides unite with water to form acids; hence they are called acid-formers or acid anhydrides. Examples are

$$CO_2 + H_2O \longrightarrow H_2CO_3$$
$$SO_3 + H_2O \longrightarrow H_2SO_4$$

Some Common Oxides

Chemical Name	Anhydride	Common Name or Ore	Formula	Uses; Occurrence
Aluminum oxide	Basic	Bauxite	Al_2O_3	Source and principal ore of aluminum, semiprecious gems, sapphires, rubies
Calcium oxide	Basic	Quicklime	CaO	Making of mortar, plaster, whitewash
Cuprous oxide	Basic	Cuprite	Cu_2O	Source of copper; colors glass red
Cupric oxide	Basic		CuO	To remove S from petroleum; colors glass green
Ferric oxide	Basic	Hematite	Fe_2O_3	Source of iron, pigment in paint, rouge; a principal ore
Iron oxide	Basic	Magnetite	Fe_3O_4	Source of iron, lodestone
Lead monoxide	Basic	Litharge	PbO	Making cut glass, pottery glaze, paint pigment; storage batteries
Magnesium oxide	Basic	Magnesia	MgO	Making milk of magnesia; insulator
Manganese dioxide	Basic	Pyrolusite	MnO_2	Catalytic agent; dry cells; source of manganese
Mercury oxide	Basic	Red oxide of mercury	HgO	Laboratory source of O_2; ointments
Zinc oxide	Basic	Zincite	ZnO	Pigment for paints; ointments; rubber antioxidant
Carbon monoxide			CO	Component of water gas and coal gas; a dangerous poison in automobile exhaust
Carbon dioxide	Acidic	Carbonic acid gas	CO_2	"Dry Ice," carbonated drinks, leavening agent; makes H_2CO_3
Hydrogen oxide	Neutral	Water	H_2O	Necessary for life and growth, universal solvent, source of power
Hydrogen peroxide	Neutral	Peroxide	H_2O_2	Bleaching agent, weak antiseptic, oxidizing agent
Nitrous oxide	Acidic	Laughing gas	N_2O	Anesthetic used by dentists
Nitric oxide	Acidic		NO	Catalytic agent used in preparing H_2SO_4
Nitrogen dioxide	Acidic		NO_2	Catalytic agent used in preparing H_2SO_4
Sulfur dioxide	Acidic		SO_2	Bleaching agent, refrigerant, preservative
Sulfur trioxide	Acidic		SO_3	Anhydride of H_2SO_4
Phosphorus pentoxide	Acidic		P_2O_5	Smoke screens, dehydrating agent, anhydride of H_3PO_4
Silicon dioxide	Acidic	Silica or sand	SiO_2	Quartz, making glass, silica gel, anhydride of H_2SiO_3

Ewing Galloway

The metal shown here was once produced in the pure state by separating it from its oxides. It is now in the process of reuniting with oxygen and is useless until it is separated again from oxygen

---

The first of these equations shows a reaction that is occurring constantly in the atmosphere and in surface water. It accounts for much erosion, corrosion, and cave formation.

The big four. You should remember that, from the viewpoint of inorganic chemistry, there are four (and only four) big classes of compounds. They are acids, bases, oxides, and salts. You have been told the relationship that exists between these compounds, as well as the methods of forming them.

EXERCISES

1. Define an oxide. Write the names and formulas of four oxides.
2. Describe two ores which are oxides.
3. What is the difference between metallic oxides and nonmetallic oxides?
4. What is an anhydride?
5. Give an example of each of the four big classes of compounds and explain why each is classed as it is.

UNIT EXERCISES

1. Devise and explain an experiment which will prove that ions exist.
2. Name some of the ways in which acids differ from each other.
3. Name the following acids: $HClO_3$, HI, H_3PO_4, and H_2S.
4. Name the following hydroxides: $Al(OH)_3$, $Fe(OH)_3$, $Cr(OH)_3$, $Cu(OH)_2$, and $Ca(OH)_2$.
5. How does hydrochloric acid help in the digestion of food?
6. List the rules for naming acids and bases.
7. Write the formulas for ten oxides. Write equations for their reaction in water.
8. Write equations for the formation of some common metallic and nonmetallic oxides.

9. Describe three general ways of producing an acid.

10. Suppose your teacher told you to make some NaOH by two different methods. How could you do it?

11. What salts are used in constructing houses?

12. Define neutralization. Give an example.

13. Write the equation for the hydrolysis of $Fe(NO_3)_3$.

14. Write the equation for the hydrolysis of $NaAl(SO_4)_2$.

15. Explain how the compound mentioned in Exercise 14 is an acid-forming compound. It is used in such baking powders as "Calumet" and "K.C." as the acid ingredient. They are called alum baking powders.

16. In some cities $Al_2(SO_4)_3$ is added to water to purify it. Explain the reaction.

17. Why is baking soda always on hand for first aid in an acid-manufacturing plant?

18. Why does baking soda neutralize excess acidity in the stomach?

19. $Mg(OH)_2$ is a weak base. Why?

20. Do the better soaps contain free sodium hydroxide? Why?

21. Write the equation for the reaction of CO_2 in limewater. Describe how the solution appears after some of the gas is bubbled through the limewater for a short time. The continued addition of CO_2 produces still another change. What is it?

22. Copper sulfate solution gives a test for free hydrogen ions. Explain how this is possible.

23. What is milk of magnesia? What is its action within the body?

24. What is quicklime called chemically? What are some of its uses?

25. Why should a considerable amount of water be used before neutralizing an acid or base spattered on your face?

26. What properties do dilute acids have in common?

27. Name two acids that are good oxidizing agents.

28. Why do some fruits, when cooked in an aluminum pan, whiten it? Is this harmful?

29. Outline and describe a method of getting citric acid from lemons. Citric acid is a white powder.

30. Name and give the formula for a liquid acid, a gaseous acid, and a solid acid. Tell how you could prepare each.

31. List as many uses for sulfuric acid as you can gather from this book and other reference books obtainable. You might draw a chart or tree showing its wide diversity of uses.

32. Repeat Exercise 31 for sodium chloride.

33. What is the difference between ammonia and ammonium hydroxide?

34. Describe the action of nitric acid upon the skin; upon silver; upon gold.

35. Why is natural water a good conductor of electricity, while distilled water is not?

36. Concentrated acids are relatively poor conductors of electricity. Why?

37. What happens to the characteristic properties of acids and bases when they are neutralized?

38. Name four general properties of bases.

39. How do the electron theory and the ionization theory tend to support each other?

40. What is an indicator? Name three indicators and explain how they act in acids and bases.

41. Write the word equation and the formula equation for the making of insoluble AgBr by combining two soluble salts.

42. Thousands of pounds of this salt, AgBr, are produced annually for the photography industry. It must be produced in darkrooms. Why?

43. What is the name applied to the type of reaction where there is an interchange of ions?

44. Write the word equation and the formula equation for the making of $NaNO_3$ (*a*) by neutralization; (*b*) when the undesired ions form an insoluble precipitate; (*c*) when the undesired product is a gas.

45. Do the same for the making of NaBr and $Al_2(SO_4)_3$.

46. Name the acids that are capable of producing acid salts. Write their formulas.

47. Write the names and formulas of two acid salts of each of the acids named in Exercise 46.

48. Name three salts which hydrolyze and give a basic reaction. Write the equations and explain why they give a basic reaction.

49. How will an acid salt ionize? What are the names of the ions?

50. Show why the acid salt sodium bicarbonate ($NaHCO_3$) will hydrolyze in solution to turn red litmus paper blue.

REFERENCES FOR FURTHER READING

Fabre, Jean-Henri. *The Wonder Book of Chemistry.* D. Appleton-Century Company, Inc., New York, 1923.

Howe, H. E. *Chemistry in Industry*, Vol. I. The Chemical Foundation, Inc., New York, 1925.

Slosson, Edwin E. *Creative Chemistry.* D. Appleton-Century Company, Inc., New York, 1919.

Looking backward and forward. At the beginning of your work in chemistry you discovered that there were certain objectives, or purposes, which you wished to attain. At this point, you should recall these major purposes and check to see which ones have been partially achieved. Turn back to pages 10–13 and review these statements so that you may have them fresh in your mind again. It would be well for you to make a list of instances which indicate at least a partial achievement of certain of these purposes. Some of them have certainly not been achieved at all. Make a list of those which fall in this group. You will wish to devote special attention to these purposes in the remainder of this course.

Much of the progress of the world has been the result of scientific thinking applied to the secrets of nature. The steps involved in this kind of thinking always include the solving of problems and checking frequently to see if objectives are being achieved. You should recall that you have been constantly solving problems, and now you are engaged in the process of checking your progress in the study of chemistry. Therefore you have had practice in thinking as a scientist does. You should constantly keep in mind all the steps in scientific thinking.

Another result that you should have gained up to this point is a reading and speaking vocabulary of science and chemistry. This will enable you to do much more research in the library than you formerly were doing and will make the rest of your study of chemistry more meaningful.

You have devoted a portion of your time to the mastery of laboratory technique. Therefore you have become familiar with the tools of the chemist. This should have caused you to get the "feel" of chemistry, as well as more knowledge of chemical reactions.

If you are going to continue your study of chemistry in college, the fundamentals which you have gained here should serve as sufficient background for your future studies.

After this study of fundamentals, you are going further into the adventure of applying chemistry to living. To interpret living chemistry properly, it is expected that you will have to refer back continually to these pages in the fore part of your book to recall important information. Moreover, you will use repeatedly the facts which you have gained here. These fundamentals are not something which you can now forget.

Have you ever read the story of some great explorer who has found adventure and fame through his conquest of the unknown? Before Admiral Byrd began his polar expedition, much thought had to be given to the equipment and supplies he would use. He must have found that the thrills of adventure came only after careful preparations. You too are now about to embark on a great adventure in chemistry. The fundamental facts which you have been studying have prepared you for the real thrill of chemistry, that of learning the applications of chemistry to daily living. The remaining portion of this book is devoted to the many ways in which chemistry affects all our lives.

PART II

CHEMISTRY
OF THE INDIVIDUAL

Life cannot exist without water

UNIT 11

The Chemistry of Water in the Body

In the study which has preceded this part of the book, you have learned many facts about the chemistry of water. For example, you know that water is composed of two parts of hydrogen by volume to one part of oxygen, and that its formula is H_2O. In addition, you have learned something of the part that water plays in the making of solutions and in ionization. These facts are important, and you should remember them; but there are many other facts about water and its relation to your own body which are also important. This unit will present for your study more information about the part that water plays in your daily living.

Have you ever been really thirsty? If you have, you know how necessary water is to the body. Though a man may live without food for several weeks, he can go without water only a few days. In fact, physical discomfort begins within a few hours and grows steadily worse as time passes.

One of the most important things in the world to you is your body, and, to maintain bodily health, water is essential. Therefore you can understand why the body needs water and why it is necessary to supply the body with the proper amount of water. Most of us drink just because we are thirsty, and we do not think of the chemical processes involved in the functioning of the body and how water enters into all these reactions. Because of this lack of understanding we are rarely conscious of the real value of water to the body.

PURPOSES TO BE ACHIEVED

1. To understand the function of water in the body.
2. To realize the importance of drinking plenty of water.
3. To know some of the conditions of the body which may result from lack or excess of water.
4. To form habits of drinking water for more healthful living.

PROBLEMS TO BE SOLVED

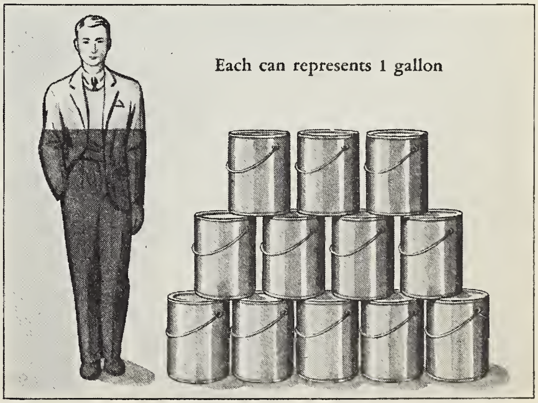
1. How much of the body is water?
2. Where does the body get the water it needs?
3. What is the function of water in the body?
4. How much water should a person drink?
5. Is it harmful to drink water with meals?
6. Are mineral waters of any value?

Problem 1. How much of the body is water?

All body tissue contains water. Most people have but little idea of the amount of water present in the body tissue. Because of the rigid structure of the body, the general conception is that it contains a very small amount of water. It is hard to believe that about two thirds of the body weight is water. This amount varies slightly with individuals, but the average person weighing 150 pounds would yield about 100 pounds of water if the water were completely extracted from his body. This amount is equivalent to that contained in six or seven average-sized water pails.

Water is a constituent of every kind of body tissue. The muscles, the skin, the teeth, and the

Two thirds of the weight of the body is water. How many gallons of water are present in the tissues of a man weighing 150 pounds?



bones all contain water as a part of their composition. Scientific analysis of the various tissues of the body has been made to determine the exact percentage of water in each kind of tissue. An inspection of the following table will help to give you some idea of the water content of some of the different kinds of body material:

Kind of Material	Percentage of Water
Blood	90
Muscles	75
Brain	85
Kidneys	82
Bones	22
Heart	78
Liver	75
Digestive juices	99.5
Teeth (enamel)	2

EXERCISES

1. Approximately what percentage of the body is water?

2. About how many gallons of water does your body contain?

3. Name three kinds of body tissue which contain a high percentage of water; three containing a low percentage.

Problem 2. Where does the body get the water it needs?

Food supplies water for body use. A seemingly simple question such as the one above might be dismissed with the statement that man drinks water to supply this essential chemical to the body. But if one studies the problem, one finds that there are two other important sources from which we secure water for body use. These sources are water in foods and water produced where food is burned (oxidized) in the body.

A most important source of water for the body is a water faucet or beverages. However, foods are just as important as a source of water. You may not consider food an important source of water, because you have never come to realize the large amount of water that is present in various foods. All food contains water, whether it be a watermelon or a dry cracker. It has been estimated that a normal diet will supply at least one half of the water needed by the body. The following table will tell you the percentage of water present in many common foods:

The Water Content of Common Foods

Food	Percentage of Water	Food	Percentage of Water
Apples	85	Eggs	74
Bacon	15	Green beans	89
Beef	60	Ham	40
Bread	38	Lamb	50
Butter	12	Macaroni (dry)	10
Cabbage	92	Milk	87
Carrots	88	Potatoes	78
Cheese	34	Steak	62
Cooked cereals	95	Strawberries	90

These foods are largely composed of water

National Dairy Council

The oxidation of food produces water. When food is burned in the body, the hydrogen of the food is oxidized to produce water. The source of oxygen is the air which is breathed and absorbed by the lungs. This equation illustrates the reaction:

$$\begin{array}{ccccccccc} \text{glucose} & + & \text{oxygen} & \longrightarrow & \begin{array}{c}\text{carbon}\\ \text{dioxide}\end{array} & + & \text{water} & + & \text{energy} \\ C_6H_{12}O_6 & + & 6\ O_2 & \longrightarrow & 6\ CO_2 & + & 6\ H_2O & + & \text{energy} \end{array}$$

The water produced in this reaction is that which is commonly referred to as water of oxidation. This water, upon formation, immediately becomes part of the blood.

EXERCISES

1. What are the three principal sources from which the body obtains water?
2. What evidence do you have that food is a source of water for the body?
3. How much water do foods contain? Give examples.
4. How does the oxidation of food produce water for body use? Write equations for this reaction.

Problem 3. What is the function of water in the body?

Water has four principal uses in the body. 1. It aids in the digestion and assimilation of food.

2. It helps to eliminate impurities from the body.

3. It helps to regulate body temperature.

4. It is essential in making the blood "fluid," so that it can do its work.

For a better understanding, let us study each of these functions.

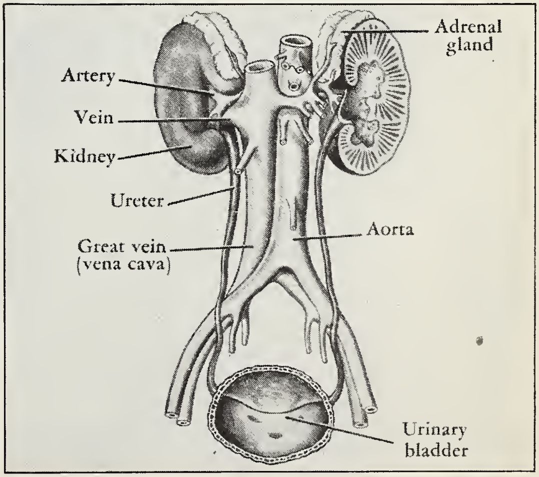
Water aids in the digestion and assimilation of food. You have learned that water is a very good solvent. The process of digestion involves the dissolving of food which is already soluble and the conversion of food which is not soluble into soluble form. Food cannot pass into the blood stream and be utilized by the body unless it is dissolved in water. The solvent action of water is thus essential to the digestion and assimilation of food.

In addition, water makes possible the passage of food from one digestive organ to another. Have you ever tried to swallow a cracker before it is thoroughly mixed with saliva? If food is not lubricated and softened by the watery saliva, it will not move readily from the mouth to the stomach or from the stomach to the intestines.

A very important habit which you should form early in life is to drink a glass of warm water every morning from fifteen to thirty minutes before breakfast. This habit is valuable for several reasons: It will help to move the food which has remained in the stomach overnight; it will stimulate the muscular movement of the stomach and intestines which causes the movement of food in the digestive tract; and it will supply water to the feces (excrement of the bowels), which will produce a softening of the excrement and make possible a healthy bowel movement. In fact, drinking a glass of warm water before breakfast prepares the digestive tract for the first food of the day and promotes the normal elimination of impurities.

Water aids in the elimination of impurities of the body. Let us assume that the average amount of water obtained by the body daily from food and drink is 128 ounces, or four quarts. This amount of water will be eliminated from the body by (1) the kidneys as urine, 40 ounces; (2) the breath as moisture, 64 ounces; (3) the perspiration, 20 ounces; and (4) the excretion of the bowels, 4 ounces. A further discussion of each of these agencies of elimination will make clearer the importance of water in the removal of impurities from the body.

The kidneys remove water, urea, and other waste materials from the blood. The solution of these materials, called urine, is stored in the bladder until it is excreted from the body[1]



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[1] Reproduced from Curtis, Caldwell, and Sherman's *Everyday Biology*, Ginn and Company.

The kidneys. The blood, which normally contains 90 per cent water, collects waste organic and inorganic substances from broken-down cells and from chemical processes in the cells. It then flows through the capillaries of the kidneys, where part of the water, with the impurities, passes through the thin walls of the capillaries, collects in the bladder, and is excreted as urine.

As the blood tends to maintain a normal consistency of 90 per cent water, only the excess amount of water will pass through the kidney walls, carrying with it the impurities. It is therefore evident that an insufficiency of water will slow down the elimination of impurities from the kidneys.

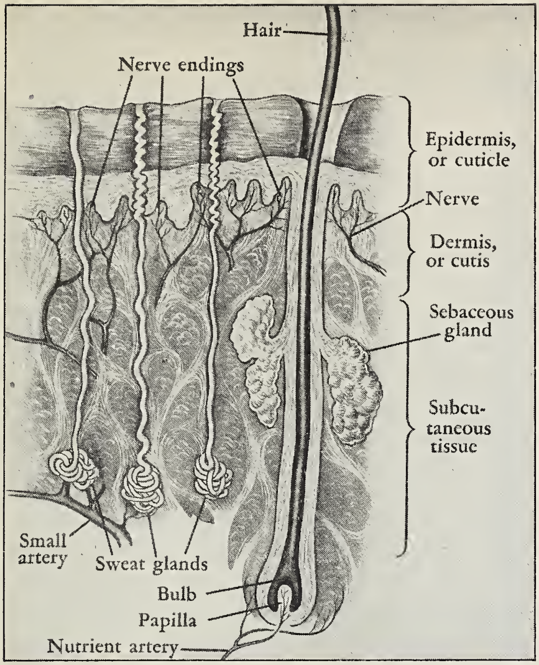
The breath. As food is burned in the cells of the body, carbon dioxide is produced. This CO_2 is carried to the lungs, from which it is exhaled through the breathing apparatus. It is essential that this exhaled air contain much moisture if this elimination is to take place properly. The purpose of this water is to help to keep the lining of the lungs, trachea, nose, and throat moist, so that it will be soft and pliable. When it is soft and pliable, the breathing apparatus is more responsive to the nerve stimulation which makes breathing possible.

Perspiration. The skin contains at least several million sweat glands. These glands make possible the elimination of perspiration. Perspiration is composed of 99.5 per cent water and 0.5 per cent impurities. The fact that a pint to a pint and a half of perspiration is eliminated every day is evidence that an appreciable amount of impurities is likewise eliminated. Some of these impurities evaporate with the evaporation of the water, while some solidify and remain in the sweat glands or on the surface of the skin. One reason for taking a daily bath is to remove these impurities from the skin.

The bowels. Although only a small amount of water is used to facilitate the excretion of waste matter through the bowels, it is nevertheless of great importance. This waste material is moved through the bowels by muscular action (peristalsis). It is possible to have the proper muscular activity if the waste matter is soft, pliable, and bulky, which is true only if enough water is present. If there is insufficient water in the bowels, the feces shrink, with a considerable diminishing of bulk. Lack of bulk causes a failure in the stimulation of the nerves which produce intestinal motion, and constipation generally results.

The body loses water during both summer and winter

Ewing Galloway



This cross-sectional diagram of the skin shows the structure and location of the sweat glands. What factors influence the amount of water given off by these glands?[1]

Whenever the body is deficient in water, it usually overcomes this deficiency by drawing water from the bowels. Consequently persons who do not drink enough water frequently suffer from chronic constipation.

Water aids in regulating the body temperature. The normal body temperature is 98.6° F. The body tends to maintain this temperature regardless of the surrounding temperature. This regulation is made possible by the fact that evaporation causes cooling. Perhaps you have noticed the cooling effect produced when you have spilled gasoline or alcohol on your hands. This is due to the rapid evaporation of the chemical.

When you exert yourself in working or exercising, more energy in the form of heat is produced in the body. This naturally tends to cause the temperature of the body to rise. To offset this tendency, beads of perspiration (sweat) break out on the body, and an increased amount of evaporation takes place, which, in turn, produces a cooling effect. This cooling is generally sufficient to maintain a constant normal temperature. It must be understood that the body is constantly perspiring and evaporation is constantly taking place. The amount of perspiration is determined by the amount of heat produced in the body and by the temperature and moisture of the surrounding air.

The temperature of the body is also influenced by the moisture in the air exhaled from the body. The warm, moist expired air contains more heat than an equal amount of air which is inhaled. The presence of moisture in the exhaled air makes it possible for this air to hold more heat. Therefore the temperature of the body tends to be lowered as a result of breathing. That water is given off in this way is very noticeable on a cold day, when the breath frosts, or fogs, because of the condensation of this moisture into very small drops.

We can aid the body in performing the task of maintaining the normal body temperature by wearing the proper kind and amount of clothing, so that the evaporation of perspiration can take place normally. There are, however, abnormal conditions under which the body temperature is increased. When this happens, we say that the body has a fever. A fever is usually caused by the fact that disease organisms are producing an excess of very toxic, or poisonous, materials in the body. As the destruction of these toxic materials is accomplished through their oxidation, the processes of oxidation in the body begin to function at a more rapid rate. This increase in oxidation is accompanied by an increase in heat production, and the body temperature rises above normal. If the temperature is to be reduced to normal, the toxic materials must be destroyed or removed. Physicians usually urge patients with temperatures above normal to drink generous amounts of water and fruit juices, thus helping the body to eliminate the toxic materials.

Water is essential in making the blood "fluid," so that it can do its work. The continuous flow of healthy blood through all parts of the body is essential to life. Blood is composed of 90 per cent water, the remaining 10 per cent being largely solid matter, including the red and white corpuscles. Without this water, the blood could not carry food

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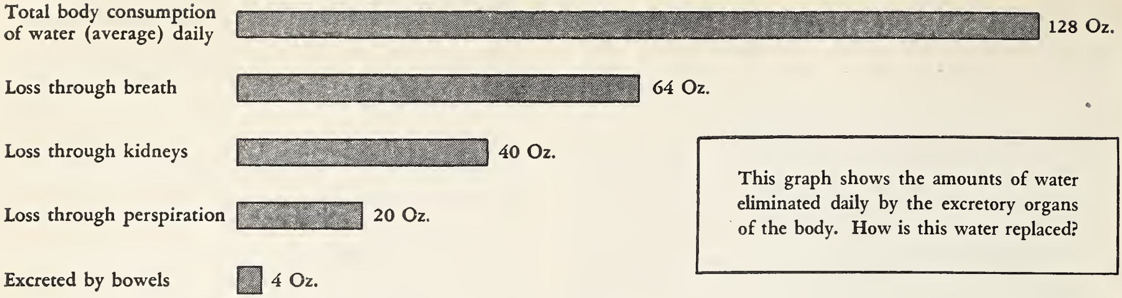
[1] Reproduced from Curtis, Caldwell, and Sherman's *Everyday Biology*, Ginn and Company.



This graph shows the amounts of water eliminated daily by the excretory organs of the body. How is this water replaced?

to the cells of the body; could not eliminate impurities from the body by carrying them to the kidneys, the skin, and the lungs; and could not perform many of the other functions which it normally carries on. It is necessary that the blood constantly maintain its normal amount of water for the proper regulation of many body processes.

EXERCISES

1. Name the four principal uses of water in the body.
2. Describe fully how water aids in the digestion and assimilation of food.
3. Through what channels is water eliminated from the body?
4. Approximately how much water is eliminated through each channel?
5. How does water aid in eliminating impurities through each of the four channels of elimination?
6. Explain how water aids in regulating body temperature.
7. What is a fever? How is it caused?
8. Why must the blood maintain a high percentage of water?

Problem 4. How much water should a person drink?

Drink six to eight glasses of water a day. The amount of water one should drink varies to a considerable extent. The person who leads a vigorous life, exercising strenuously, will require more water than one who leads an inactive life. Likewise, the humidity and temperature of the air, the diet and the age of a person, help to determine the amount of water required by the body.

If a person drinks water every time he feels thirsty, the amount of water drunk will generally be sufficient for his body requirements. However, there are many individual cases where this feeling cannot be considered a reliable guide to the amount of water that should be drunk.

The average person requires about four quarts, or 128 ounces, of water a day to regulate properly the various body processes and to replenish the body with water lost through excretion. The food that you eat will account for at least one half of this water. The other half (about eight glasses) must be supplied by drinking water and beverages. The habit of drinking from six to eight glasses of water a day is highly recommended.

Many people believe that drinking water in larger quantities than those recommended above is beneficial to health. The most recent investigations have indicated that this is not true. Many ill effects, such as strain on the heart and kidneys, have resulted from drinking too much water. The rapid drinking of large quantities of water after excessive exercise is known to have caused digestive disturbances and headaches. After strenuous exercise it is advisable to sip water slowly.

The following schedule is recommended as supplying sufficient water for a normal person:

One or two glasses on rising . .	1–2
One glass with each meal . . .	3
One glass between meals . . .	2
One glass on retiring	1
	7 or 8 glasses

EXERCISES

1. Why should you drink from six to eight glasses of water a day?
2. What factors may enter into the amount of water one should drink?
3. Is thirst a reliable indicator of the amount of water a person should drink? Why or why not?

4. How much water can you expect to get from the food you eat?
5. Is it possible to drink too much water? Why or why not?
6. How often should water be drunk?

Problem 5. Is it harmful to drink water with meals?

Water and digestion. The belief that drinking water with meals will produce ill effects has been disproved. Experiments have shown that the chemicals and other substances responsible for the digestion of food are just as effective in dilute solutions as in more concentrated solutions.

The one danger in the use of water during a meal is that it may be substituted for proper chewing. The mixing of food with saliva moistens and lubricates the food, so that it passes readily into the stomach. The same effect can be produced by filling the mouth with water when food is present. This, of course, discourages the chewing of food, with the result that it is not mixed with sufficient saliva to start the digestion of starches and sugars. If you chew your food properly, water, when drunk with meals, will aid the digestive process.

EXERCISES

1. How does water aid digestion?
2. What is the danger of drinking water with meals?
3. How should water be drunk with meals?

Problem 6. Are mineral waters of any value?

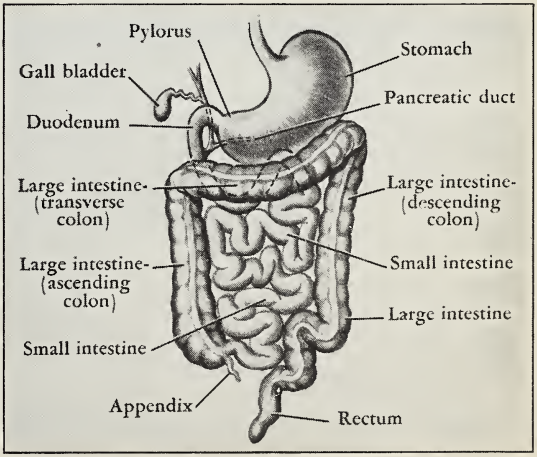
Mineral springs. In many sections of the United States and in many other parts of the world, there are mineral springs. These springs vary in nature; some are soda springs, while others are termed sulfur, iron, lithia, and radium springs. Some are hot, and others are cold. Wherever these springs are found, it seems customary for some enterprising promoter to build a fine hotel and begin a campaign of advertising the location as a mineral-springs health resort. This generally results in an influx of people who are seeking an easy way to healthful living.

Very frequently the person who goes to such a resort has broken every habit of healthful living. His body is in an advanced stage of ill health. After he registers, he is told to drink all he can of the mineral water available. It is common to see him walking around the spacious grounds, carrying a cup and stopping at every fountain for a drink of the magic water. In addition, he is told to report to the bathhouse at regular periods. Here he is told to bathe in the mineral water, and, in many cases, he is given steam baths. After a bath he is given a vigorous rubdown by an attendant. His schedule calls for long periods of resting. After several weeks he leaves the resort, feeling fine and with a great desire to tell his friends of the wonders of mineral waters.

Do mineral waters contain minerals? It is true that mineral waters contain minerals; in fact, all water (except distilled water) contains minerals. The water of soda springs contains sodium bicarbonate ($NaHCO_3$), and sulfur water contains hydrogen sulfide (H_2S). Iron spring water may contain several soluble salts of iron; lithia water, salts of lithium. In addition, in many of these waters are found other soluble salts, such as Glauber's salt (Na_2SO_4) and Epsom salts ($MgSO_4$), both of which are known for their laxative qualities.

Are mineral waters valuable to health? The value of mineral water in maintaining and restoring normal health is very doubtful. Minerals that the body needs are well supplied through the diet. Calcium is probably the only mineral which may be deficient in the average diet. It is interesting to note that mineral springs are rarely, if ever, advertised as supplying calcium to the body. It has not been

Diagram of the large and small intestines of the body. What are the purposes of water in the intestinal tract?



scientifically proved that mineral water is capable of performing the miracles advertised.

Do health resorts restore the health of patients? In general, the body always needs a reasonable amount of exercise, plenty of rest, a wholesome balanced diet, and a favorable mental state. Certainly a modern health resort can supply all these. The exercise is made sure of by regular massage, rest is definitely scheduled, the cost makes possible the best of food, and the beautiful spacious setting, coupled with faith in the mineral water, produces a healthful mental attitude. Can it be said that it is the mineral water that has performed miracles, or is it merely a change in habits of living that is responsible?

Mineral-water crystals. One of the latest methods of marketing mineral water is to evaporate it, place the crystals so obtained in attractive bottles, and ship the bottles to consumers. These bottled crystals are advertised as a convenient way of drinking yourself back to health. An analysis of some of these crystals shows that they consist of 98 per cent Glauber's salt, 1 per cent table salt, 0.5 per cent Epsom salts, and another 0.5 per cent of small quantities of other minerals. You are familiar with the fact that Epsom salts are a laxative. Glauber's salt has been generally used as a laxative for horses. Actually, then, these crystals are of no more value than a less expensive laxative.

EXERCISES

1. How do mineral springs aid in restoring health? Can health be restored in other ways? How?

2. Do all drinking waters contain minerals?

3. What are some common minerals found in so-called mineral waters?

4. What does the body need to restore health?

5. How may mineral waters be transported to the consumer?

PROBLEMS FOR FURTHER STUDY

1. Is it advisable to drink large quantities of water when one has a cold?

2. Will wetting the hair with water cause baldness?

3. Does drinking large quantities of water cause a person to become fat?

4. How is the amount of moisture eliminated by the body measured?

5. What dangers may result from drinking excessive amounts of water?

6. Make a survey of the class to determine the average amount of water that is drunk.

7. Consult a physician or other medical authority to learn the modern practices in the treatment of fever.

8. Are sweat and steam baths healthful?

Will a glass a day keep the doctor away?

Ewing Galloway

UNIT EXERCISES

Some of the statements which follow are true, and some are false. On a separate sheet of paper write the word *true* for each statement that is true and the word *false* for each statement that is false. Write nothing for those statements about which you are doubtful. Rewrite the false statements so that they are true.

1. It is possible for a person to do without water for a longer period of time than without food.

2. About 67 per cent of the body weight is water.

3. The teeth are the only body tissue which contain no water.

4. Six to eight glasses of water a day will supply all the water that the body needs.

5. When glucose unites with oxygen in the body cells, water is produced.

6. All foods contain water which may be used by the body.

7. Warm water, drunk before breakfast, has a tendency to upset the stomach.

8. Digestion involves the dissolving of food in water.

9. The body needs about two quarts of water a day.

10. When the body has a deficiency of water, it usually draws water from the bowels to overcome the deficiency.

11. An increase in perspiration during exercise has a tendency to increase the body temperature.

12. A person with fever should use water sparingly.

13. Food supplies about one half of the water that the body needs.

14. Drinking water before breakfast is an aid to a healthy bowel movement.

15. A person who never exercises may need only one or two glasses of water a day.

16. The more water a person drinks, the more healthy he will be.

17. If food is chewed well, it is better not to drink water with meals.

18. A person should never drink mineral water.

19. The important factors which tend to benefit a person who goes to a mineral-springs resort are rest, exercise, and pleasant surroundings.

20. Mineral waters often contain chemicals which act as laxatives.

21. Water is essential in making the blood "fluid," so that it can do its work.

22. A fever is caused by the body's becoming overheated.

23. Perspiration aids in regulating the body temperature.

24. Water keeps the feces soft and pliable so that the bowels move normally.

25. Most of the water lost by the body is eliminated through the sweat glands.

REFERENCES FOR FURTHER READING

The following references will provide you with information to be used in investigating any of the "Problems for Further Study" that you may choose:

BAUER, W. W. *Health Questions Answered.* The Bobbs-Merrill Company, Indianapolis, 1937.

BOGERT, L. JEAN, and PORTER, MAME T. *Dietetics Simplified.* The Macmillan Company, New York, 1937.

CRISP, KATHERINE. *Be Healthy.* J. B. Lippincott Company, Philadelphia, 1938.

DIEHL, HAROLD S. *Healthful Living.* McGraw-Hill Book Company, Inc., New York, 1935.

FISHBEIN, MORRIS. *Fads and Quackery in Healing.* Covici-Friede, Inc., New York, 1933.

FISHBEIN, MORRIS. *Modern Home Medical Adviser.* Doubleday, Doran & Company, Inc., New York, 1935.

FISHBEIN, MORRIS. *Your Diet and Your Health.* McGraw-Hill Book Company, Inc., New York, 1937.

WILLIAMS, J. F. *Personal Hygiene Applied* (Fifth Edition). W. B. Saunders Company, Philadelphia, 1934.

UNIT 12

The Chemistry of Foods and Nutrition

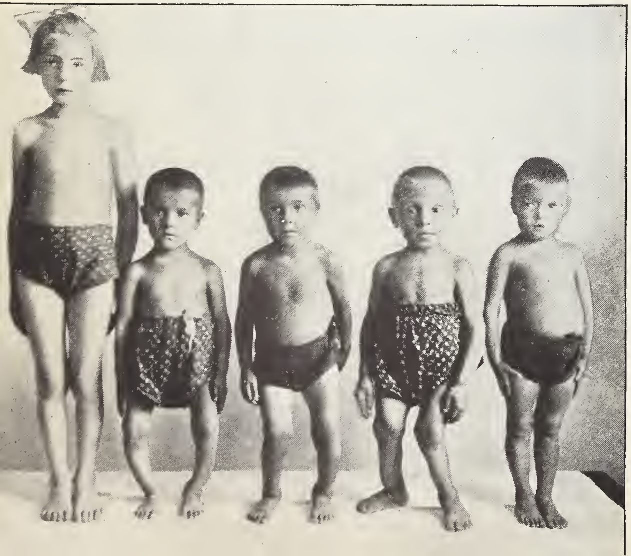
The results of a physical examination given to one thousand students in a large city high school, located in an underprivileged district, showed that 30 per cent were suffering from the effects of faulty nutrition (malnutrition). Many of these students were suffering from bone deformities, such as curvature of the spine, knock-knees, and bowlegs, caused by improper diet. Some had decayed and crooked teeth, and many were underweight. Lack of mental alertness and susceptibility to infection were evident. It seems unreasonable that, in this age of large supplies of foodstuffs, children should have to go through life with deformed bodies caused by unbalanced diets. And yet thousands of children are doomed to grow up with bodies that will never be normal.

What is the underlying cause of this condition, and what can be done about it? In too many cases, parents still hold the opinion that appetite is a reliable guide to the selection of food. If a child eats plenty, he is supposed to be healthy, and the kind of food he eats is not considered an important matter by many parents. Although many cases of malnutrition are due to a limited family budget which renders impossible the purchase of the right amount and kinds of food, many other cases are the result of ignorance of what constitutes a balanced diet, and the inability of parents to make proper and economical purchases.

The solution of this most important problem seems to lie in education. Knowledge of the importance of the right kind of food for healthful living, of what constitutes a balanced diet, of the effects of eating improper food, and of economical methods of buying food would go a long way toward eliminating the conditions that now exist.

The little Polish children on the right in this picture are the same age as the normal girl on the left. Malnutrition due to improper and insufficient food caused this condition. They lived in war-torn Europe when thousands died of starvation

Extension Service, United States Department of Agriculture



PURPOSES TO BE ACHIEVED

1. To become aware of the part played by food in maintaining a healthy body.
2. To become familiar with some of the fundamentals of organic chemistry so that the chemistry of life processes may be better understood.
3. To gain an understanding of what constitutes a balanced diet.
4. To provide your body with a balanced diet through a knowledge of how to choose the right kind of food.
5. To realize that many of the common ailments may be caused or aggravated by the improper use of food.
6. To obtain scientific proof of the necessity of forming proper habits of health as related to the selection, use, and digestion of food.
7. To become "consumer-wise" toward unscientific sources of information which would "sell" you ideas and food products of a doubtful or dangerous nature.

PROBLEMS TO BE SOLVED

1. What knowledge of organic chemistry is essential to an understanding of the chemistry of foods and nutrition?
2. How is food changed in the body so that it can be utilized?

3. What are the properties and characteristics of the food nutrients?
4. How is food digested?
5. How is food absorbed and used in the body?
6. What is the energy requirement of the body?
7. What are the best sources of the food nutrients?
8. What dangers may result from the improper use of food?
9. Is it wise to "diet"?
10. How do emotional disturbances affect digestion?

Problem 1. What knowledge of organic chemistry is essential to an understanding of the chemistry of foods and nutrition?

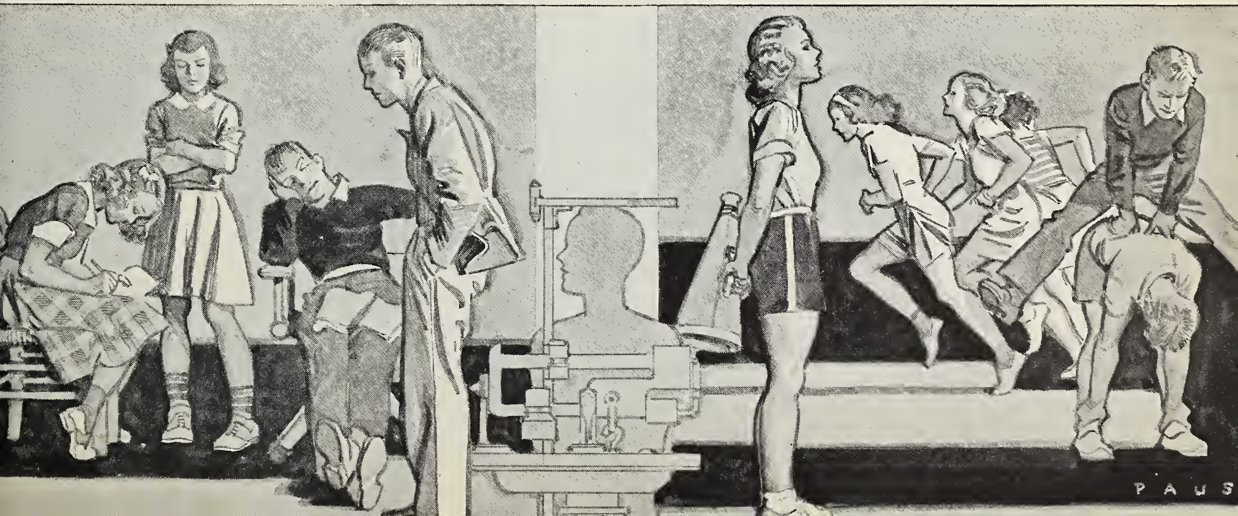
Food chemistry involves organic chemistry. In Part I you have gained some knowledge of inorganic chemistry. The study of the chemistry of food and nutrition requires some knowledge of organic chemistry. Before proceeding with a discussion of the problems suggested in connection with foods and nutrition, it will be beneficial for you to become acquainted with the field of organic chemistry.

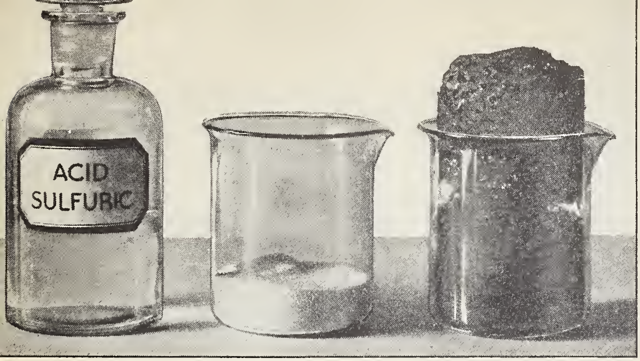
What is the extent of the field of organic chemistry? It was first thought that organic chemistry involved compounds that could be manufactured only by and within plants or animals. However, in 1828, Wöhler, a German chemist, prepared urea, an organic animal substance, from ammonium cyanate, an inorganic substance. Since this discovery, chemists everywhere have prepared thousands of organic compounds, which formerly were supposed to be formed only within plants or animals. These compounds have all been found to contain the element carbon. Hence organic chemistry is defined as *the study of carbon compounds.*

What are the properties of organic compounds? In comparing organic and inorganic compounds, several general properties are significant. Most organic compounds are *not as active chemically* as inorganic compounds. However, organic compounds are *unstable at high temperatures.* When heated to a high temperature, organic compounds *char.* This is evident when bread is toasted to black carbon. Charring is considered a test for organic compounds. Many carbon compounds are *insoluble in water.* Solvents such as alcohol, ether, gasoline, and chloroform are generally used. Carbon compounds are more complex in chemical composition than inorganic compounds. Observe the formula of stearic acid, $C_{17}H_{35}COOH$, or cane sugar, $C_{12}H_{22}O_{11}$, as compared with the formula of such an inorganic compound as sulfuric acid, H_2SO_4.

How are organic compounds classified? As in the case of inorganic compounds, which are classified as acids, bases, salts, and oxides, there are logical groupings of organic compounds. Several of these groupings are large and contain many compounds. It must be understood that organic chemistry is much more complicated in its nature than inorganic chemistry. A complete study of it demands much more knowledge of chemistry than is demanded of

A balanced diet and food in sufficient amounts make a big difference in the physical and mental health of young men and women





This picture shows a common method of testing a substance to determine whether it is organic or inorganic. What chemical element remains when sugar is treated with concentrated sulfuric acid?

high-school students. It is, therefore, necessary in this study of organic chemistry to proceed in a very simple manner. This elementary information should be valuable in your study of foods and nutrition and, in addition, should serve as a background for other units in this book which are related to organic chemistry. In the beginning it is desirable to study the simplest grouping, or family, the *hydrocarbons*.

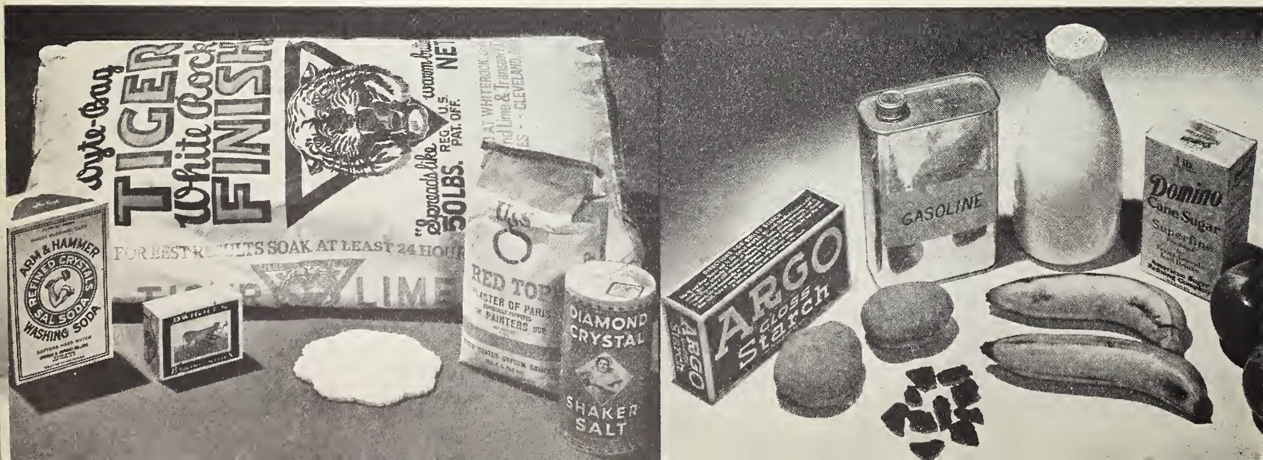
What are hydrocarbons? Hydrocarbons are one of several large families of organic compounds. As the name implies, they contain *only the elements hydrogen and carbon.* Several hundred compounds in this family are known. To simplify their study, these hydrocarbons are classified into groups of compounds known as the methane or paraffin series, the ethylene series, the acetylene series, and the benzene series. In each series there are a number of closely related compounds. Furthermore, many compounds, called *derivatives* or *substitution products*, are possible by replacing one or more hydrogen atoms with other atoms or groups of atoms. Derivatives are among the most important compounds in the field of organic chemistry, and an attempt will be made to familiarize you with some of them. For present purposes, it will be necessary to study only the methane series and several of the derivative compounds which may be obtained from this series.

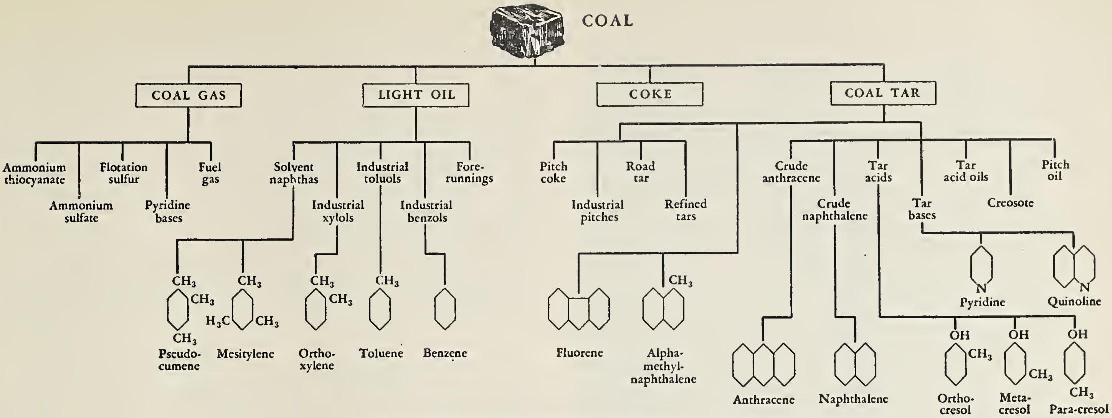
What are the characteristics of the methane series? The methane series is a group of compounds of the hydrocarbon family in which each compound differs from the preceding one by a common group (CH_2). This is illustrated by the formulas for the first five members of the methane group: methane (CH_4), ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), pentane (C_5H_{12}).

The chemist uses a general formula for obtaining the specific formula for any compound in this series. This formula is C_nH_{2n+2}. There are a large number of compounds possible in such a series. Hexecontane ($C_{60}H_{122}$) is an example of a compound having a large number of carbon atoms. It is a constituent of lubricating oils. You will notice that hexecontane conforms to the general formula for hydrocarbons in this series in that the number of hydrogen atoms is two times the number of carbon atoms plus two.

In isolating the various compounds of this series, a direct relationship has been found between the number of carbon atoms and the physical state of a particular compound. The lower carbon compounds, such as methane (a constituent of natural gas), are gases. As the carbon atoms increase, the compounds become liquids (hexane, C_6H_{14}, a component of gasoline), and compounds with a still higher number of

Some common inorganic and organic substances





A few of the many products obtained from coal

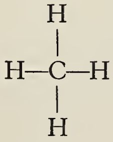
Koppers Company

carbon atoms are solids (eicosane, $C_{20}H_{42}$, a constituent of paraffin).

How are organic formulas written? In the study of inorganic compounds it is customary to write the formulas so that the symbols of elements have subscripts to denote the number of atoms of each particular element. Thus H_2O denotes that a molecule of the compound water contains two atoms of hydrogen and one of oxygen. Also, in inorganic chemistry, formulas are written so that the metallic element precedes the nonmetallic, but no attempt is made to show the *arrangement* of the atoms in the molecule. Thus H_2SO_4 (sulfuric acid) is written to indicate that the hydrogen ion is metallic in its action and the sulfate ion is nonmetallic. This type of formula is called an *empirical* formula.

In organic chemistry a *structural* formula is also used. This indicates the arrangement of the atoms in the molecule.

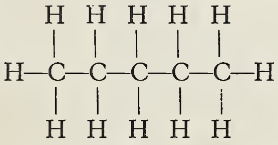
Experimentation has proved that the *carbon atom of organic compounds always has a valence of 4* and is found at or near the center of the molecule. Thus methane can be written empirically as CH_4 or structurally as



$$\begin{array}{ccccc} & & H & & \\ & & | & & \\ H & — & C & — & H \\ & & | & & \\ & & H & & \end{array}$$

From this formula, one can visualize the carbon atom at the center of the molecule, with the four hydrogen atoms grouped around it and held to it by invisible "chains" of force known as *bonds*. These bonds also represent the valence, and, as is to be expected, there must always be four bonds for each carbon atom. The valence of hydrogen is known to be 1, which is shown by the single bond for each hydrogen atom in the structural formula of methane.

The structural formula for pentane (C_5H_{12}) may be written similarly:

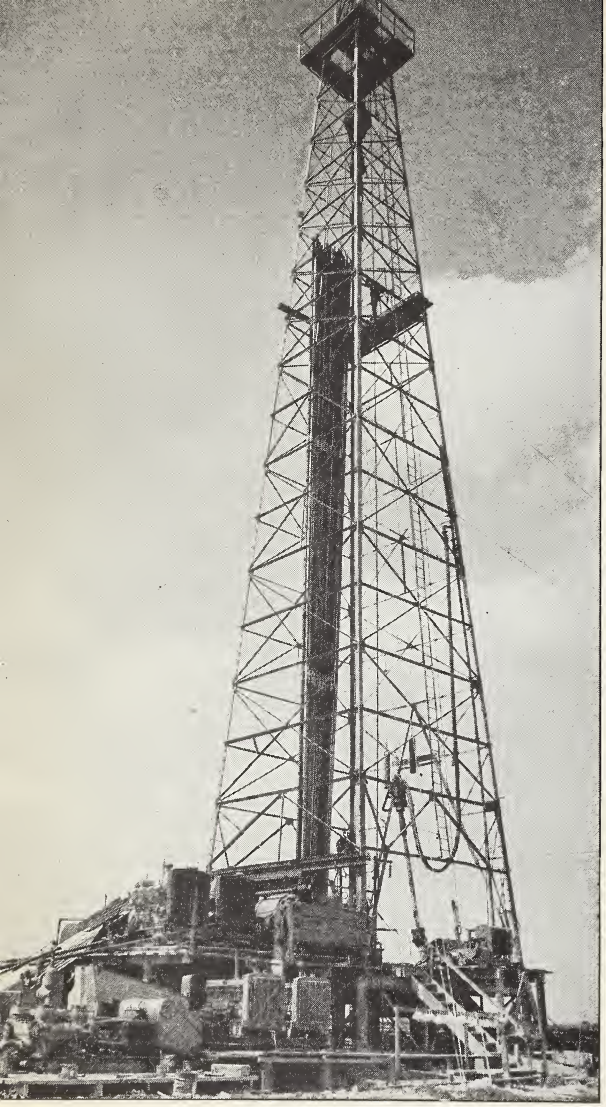


$$\begin{array}{ccccccccccc} & & H & & H & & H & & H & & H & & \\ & & | & & | & & | & & | & & | & & \\ H & — & C & — & C & — & C & — & C & — & C & — & H \\ & & | & & | & & | & & | & & | & & \\ & & H & & H & & H & & H & & H & & \end{array}$$

This formula exhibits, again, the fact that each carbon atom has four bonds and each hydrogen atom one bond, representing their valences.

What derivatives, or substitution products, of methane are possible? A derivative, or substitution product, is one in which one or more hydrogen atoms of a hydrocarbon have been replaced by another atom or group of atoms. Many of these products are possible. For an understanding of the chemistry of foods and digestion, and of other units to follow, it is desirable to show the formation of such derivatives as *alcohols*, *organic acids*, and *esters*.

For a present understanding of these compounds you may consider them similar to some inorganic compounds that you have already studied. For example, sometimes an alcohol is likened to a base,



The gas which comes from this well is composed chiefly of methane (CH_4) but usually contains also small amounts of other gaseous hydrocarbons

since they both contain the OH radical. Thus a common alcohol, ethyl alcohol (C_2H_5OH), and a common base, lye ($NaOH$), both have the OH radical in their molecules. However, alcohols do not have all the properties of bases in that they do not ionize, or affect, indicators. Organic acids are similar to inorganic acids because they both contain replaceable hydrogen. In addition, most of the soluble organic acids are sour and affect indicators in the same way as inorganic acids. Some common organic acids are acetic ($HC_2H_3O_2$, or CH_3COOH) and citric ($H_3C_6H_5O_7$, or $C_3H_4OH(COOH)_3$). When an inorganic acid reacts with a base, a salt is formed. Likewise, the reaction between an organic acid and an alcohol produces an ester. For this reason esters resemble salts. The equations below show the similarities:

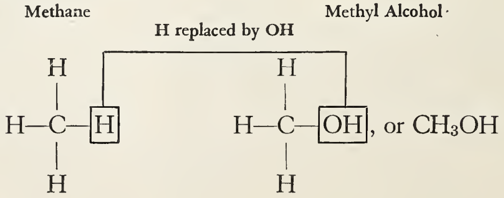
$$\overset{\text{hydrochloric acid}}{HCl} + \overset{\text{sodium hydroxide}}{NaOH} \longrightarrow \overset{\overset{\text{(salt)}}{\text{sodium chloride}}}{NaCl} + \overset{\text{water}}{HOH}$$

$$\overset{\text{acetic acid}}{HC_2H_3O_2} + \overset{\text{ethyl alcohol}}{C_2H_5OH} \longrightarrow \overset{\overset{\text{(ester)}}{\text{ethyl acetate}}}{C_2H_5C_2H_3O_2} + \overset{\text{water}}{HOH}$$

The first reaction takes place instantaneously, but the second reaction, because of the lack of ionization of organic compounds, takes place very slowly.

The relationship of an alcohol to a hydrocarbon. When one or more hydrogen atoms of a compound in the methane series is replaced by a hydroxyl radical, an alcohol is produced. Two alcohols familiar to most of us are grain, or ethyl, alcohol (C_2H_5OH) and wood, or methyl, alcohol (CH_3OH). In addition to these two alcohols, a great number of other alcohols are known. Among those commonly used are propyl alcohol (C_3H_7OH), a constituent of many of the cheaper-priced rubbing alcohols, glycerin ($C_3H_5(OH)_3$), which is commonly used as an antifreeze and in the manufacture of many cosmetics, and ethylene glycol ($C_2H_4(OH)_2$), which is sold under the trade name of "Prestone."

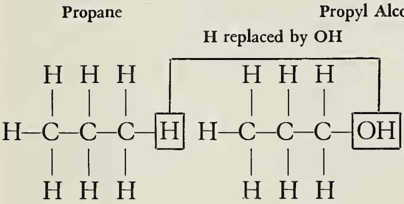
The formation of these alcohols may be shown best by the use of the structural formula. In methane (CH_4), when a hydrogen atom is replaced by a hydroxyl group, the formula becomes CH_3OH (methyl alcohol). Although the laboratory process of making alcohols from hydrocarbons involves several intermediate reactions, the following structural picture will show the relation between methane and methyl alcohol:



$$\begin{array}{ccccc} & \text{Methane} & \text{H replaced by OH} & \text{Methyl Alcohol} & \\ & \begin{array}{ccc} & H & \\ & | & \\ H- & C & -\boxed{H} \\ & | & \\ & H & \end{array} & & \begin{array}{ccc} & H & \\ & | & \\ H- & C & -\boxed{OH} \\ & | & \\ & H & \end{array} & \text{, or } CH_3OH \end{array}$$

Name	Formula	How Made	Uses
Methyl alcohol (wood alcohol)	CH_3OH	Wood distillate	Varnishes, lacquers, antifreeze
Ethyl alcohol (grain alcohol)	C_2H_5OH	Fermentation of grain	Liquors, extracts, perfumes, medicines, solvent, antifreeze
Propyl alcohol	C_3H_7OH	From propane	Rubbing alcohol, solvent
Glycerin	$C_3H_5(OH)_3$	Manufacture of soap	Antifreeze, cosmetics, explosives
Glycol	$C_2H_4(OH)_2$	From ethane	Antifreeze, explosives

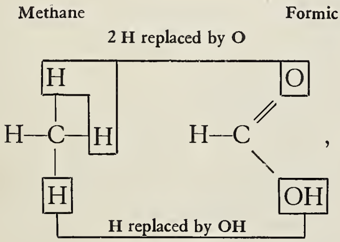
If one of the hydrogen atoms in propane (C_3H_8) is replaced by a hydroxyl group, the formula becomes C_3H_7OH (propyl alcohol). The structural formula is



, or C_3H_7OH

It is also possible to replace three hydrogen atoms of propane with three hydroxyl groups. The alcohol thus obtained is called glycerin ($C_3H_5(OH)_3$). You should notice that the OH group is common to all alcohols. The table at the top of this page shows some of the well-known alcohols.

Organic acids. An organic acid is produced when one hydrogen atom of a compound of the methane series is replaced by the hydroxyl group, and two other hydrogen atoms by an oxygen atom. For example, the acid derivative of methane is known as formic acid (HCOOH) and may be shown structurally as follows:



, or HCOOH

Similarly, acetic acid (CH_3COOH) may be shown to be a derivative of ethane (C_2H_6), and stearic acid ($C_{17}H_{35}COOH$) becomes a derivative of octadecane ($C_{18}H_{38}$).

Organic acids may be produced by the oxidation of an alcohol. Thus, when ethyl alcohol is oxidized, acetic acid is formed as represented in the equation

$$C_2H_5OH + O_2 \longrightarrow CH_3COOH + H_2O$$

The group COOH is called the *carboxyl radical* and is characteristic of the formulas of all organic acids. Some of the common organic acids that are derivatives of the hydrocarbons are as follows:

Name	Formula	Where Found
Formic	$HCOOH$	Ants, bees, and nettles
Acetic	CH_3COOH	Vinegar
Butyric	C_3H_7COOH	Rancid butter
Palmitic	$C_{15}H_{31}COOH$	Rancid vegetable oils
Stearic	$C_{17}H_{35}COOH$	Rancid animal fats

In following the digestive process, it will be interesting to note that the digestion of fats involves their change to fatty acids. Acids derived from the methane series are called fatty acids. In the study of the digestion of fat we are particularly interested in stearic, palmitic, and oleic acids.

How are esters formed? An organic ester is produced by the reaction between an organic acid and an alcohol. A typical case will show the formation of the ester methyl acetate:

$$\overset{\text{acetic acid}}{CH_3COOH} + \overset{\text{methyl alcohol}}{CH_3OH} \longrightarrow \overset{\text{methyl acetate}}{CH_3COOCH_3} + \overset{\text{water}}{HOH}$$

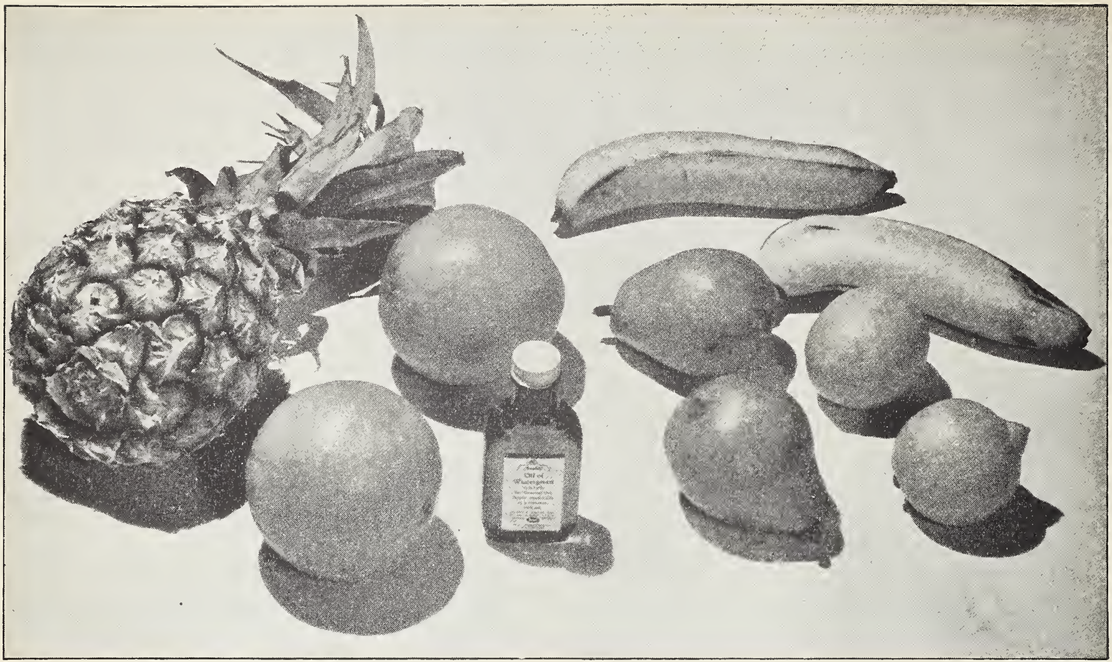
Another illustration, which uses a more complex acid and one of higher carbon content, is as follows:

$$\overset{\text{stearic acid}}{3\,C_{17}H_{35}COOH} + \overset{\text{glycerin}}{C_3H_5(OH)_3}$$

$$\longrightarrow \overset{\text{glyceryl stearate}}{(C_{17}H_{35}COO)_3C_3H_5} + \overset{\text{water}}{3\,HOH}$$

Glyceryl stearate is a fat called stearin.

With this very brief and simple introduction to organic chemistry, it is now possible to proceed with


Ewing Galloway

The odor of these substances is due to the presence of esters. You can make esters in the laboratory by combining organic acids with alcohols

a study of food and nutrition. It must be understood that organic chemistry is a much larger field than inorganic chemistry. To study the thousands of known organic compounds is far beyond the scope of this book. Whenever it becomes necessary to use further information about the field of organic chemistry, we will build upon the fundamental material that has been presented.

EXERCISES

1. What is organic chemistry?
2. List the general properties of organic compounds.
3. What are hydrocarbons?
4. What is a derivative, or substitution product?
5. What are the characteristics of the methane series of hydrocarbons?
6. Name and give formulas for the first five compounds of the methane series.
7. Explain and give examples to show the difference between an empirical and a structural formula.
8. Write the structural formula for propane.
9. What classes of inorganic compounds may be compared to alcohols, organic acids, and esters? Why are these comparisons possible?
10. Name and give the formulas for three common alcohols.
11. How may alcohols be derived from compounds of the methane series? Give an example.
12. How may an alcohol and an organic acid be recognized from their formulas?
13. How is an organic acid produced?
14. Name and give the formulas and uses of four organic acids.
15. How are esters formed? Write an equation to show this reaction.

Problem 2. How is food changed in the body so that it can be utilized?

The six food nutrients. Laboratory analysis shows that foods are composed of six classes of compounds that are useful to the body. They are proteins, fats, carbohydrates, minerals, vitamins, and water. Each of these food substances has a definite role in the maintaining of a healthy body. They are frequently referred to as *nutrients.*

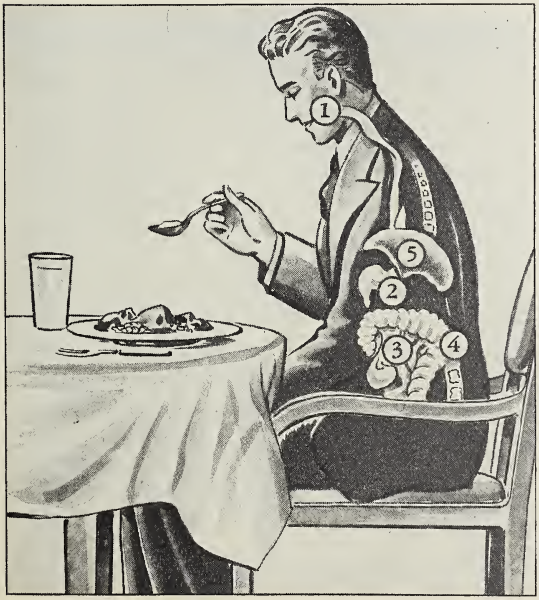
The body requires food for three purposes: (1) *to obtain energy*, (2) *to build, maintain, and rebuild* *tissue*, and (3) *to regulate body processes.* The food nutrients may be classified under these purposes as follows:

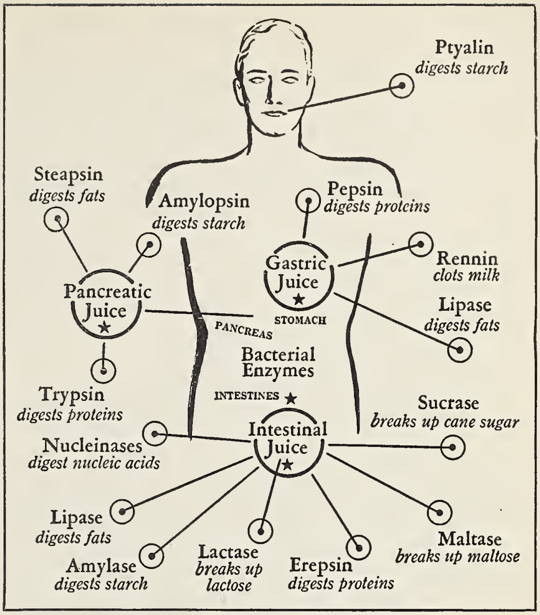
Provide Energy	Build, Maintain, and Rebuild Tissue	Regulate Body Processes
Proteins Fats Carbohydrates. (Fats and carbohydrates build fatty tissue)	Proteins Minerals	Minerals Vitamins Water

In order that these purposes may be attained, the food must be subjected to three essential processes: (1) *digestion*, (2) *absorption*, and (3) *assimilation*.

Digestion is a process by which food is made soluble so that it can be used by the body. Digestion is made possible by mechanical action in which chewing and the muscular activity of the digestive tract reduce the food to finely divided particles which are more easily dissolved in water. In addition, digestion includes chemical changes caused by the action on the foods of the digestive juices from various glands.

The digestive system is made up of (1) the mouth, in which starch is partially digested by an enzyme in the saliva; (2) the stomach, where the hydrochloric acid and enzymes of the gastric juice start the digestion of proteins; (3) the small intestine, where a number of enzymes from the pancreas and the intestinal glands act upon the partially digested and undigested food to complete the process; (4) the large intestine, which serves as a receptacle for undigested material; (5) the liver, from which bile is secreted into the small intestine to aid in the digestion of fats[1]





The enzymes of the digestive system[1]

Absorption is the process by which the digested, dissolved food passes through the intestinal walls into the blood and lymph. *Assimilation* is an all-inclusive term used to name the changes which take place in food after it has been absorbed from the digestive tract and carried to the living cells. The process involving the oxidation of food to produce energy is known as *energy metabolism.*

In the digestive process the importance of mechanical action should not be underestimated. Without it, the chemical processes would fail to function properly. However, from the point of view of this particular discussion, the chemical action of the digestive juices plays the most important role. In these digestive secretions there are important chemical substances known as *enzymes.*

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[1] From Bunzell and Nisenson's *Everyday with Chemistry.* Grosset & Dunlap, publishers.

It is necessary that you understand the action of enzymes in the digestion of food.

Enzymes. Enzymes are organic catalytic agents. They are found in plant and animal cells. Their structural composition is not definitely known. The enzymes are produced by glands which secrete digestive juices into the mouth, stomach, and intestines.

There are many digestive enzymes. For the sake of simplicity, they may be classed according to the nutrients that they help to digest.

1. The *proteases*—acting on protein.
2. The *lipases*—acting on fats.
3. The *amylases*—acting on carbohydrates.

In each of these classes there are several enzymes, the most important of which will be considered in connection with the digestion of each nutrient involved. The purpose of a digestive enzyme is to aid in breaking down, through catalytic action, the complex food nutrients into simpler substances so that water may act upon the food and prepare it for absorption into the blood stream.

EXERCISES

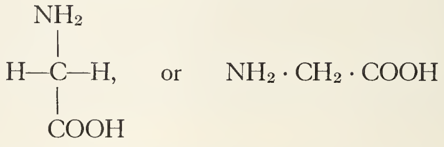
1. Name the six food nutrients.
2. For what purposes does the body require food?
3. Which nutrients help the body to attain each of these purposes?
4. What processes must food be subjected to before these purposes are attained?
5. Define digestion, absorption, and assimilation.
6. What is an enzyme? What does it do?

Problem 3. What are the properties and characteristics of the food nutrients?

Proteins. The exact structure of proteins has not been determined. It is known that they are very complex in chemical composition, probably containing hundreds of atoms in each molecule. Their complexity is further indicated by the fact that they have a high molecular weight. The probable molecular weight of egg albumin, a protein, is 34,000, and that of casein, another protein, is about 98,000. You will notice that the weight of these molecules is much greater than that of an inorganic molecule, such as baking soda ($NaHCO_3$), which has a molecular weight of 84. Proteins always contain *carbon*, *hydrogen*, *oxygen*, and *nitrogen*, and *sometimes sulfur*, *phosphorus*, or *iron*.

Proteins are constituents of both plant and animal cells. The plant builds its own protein from inorganic materials obtained from the soil and the air. Such is not true of the animal. The animal must obtain protein from food (that is, secondhand) and resynthesize, or rebuild, it into protein of the kind peculiar to its own tissue. Thus man must eat protein supplied by plants and other animals in the form of food, and through digestion, absorption, and assimilation resynthesize it into the kind of protein that he needs.

Proteins generally exist in the amorphous form, although some have been obtained in the crystalline form. Chemically they are composed of various combinations of amino acids. These acids are protein substances which contain the NH_2 (amine) group. The structural formula of one of the more simple of the twenty-two known amino acids, glycine, may be written as follows:

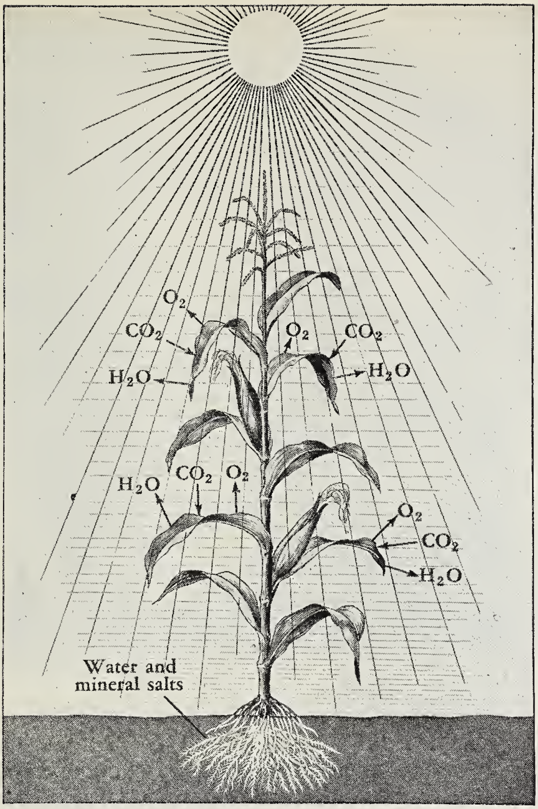


$$\begin{array}{c} NH_2 \\ | \\ H{-}C{-}H, \\ | \\ COOH \end{array} \quad \text{or} \quad NH_2 \cdot CH_2 \cdot COOH$$

It must be understood that all proteins must be prepared for absorption by breaking down the complex protein molecules into the simpler, soluble amino acids. This is accomplished in the digestive tract by hydrochloric acid and the catalytic action of the protease group of enzymes. The change to amino acids takes place in both the stomach and the small intestine.

Carbohydrates. Carbohydrates are organic compounds composed of *carbon*, *hydrogen*, and *oxygen*. The hydrogen and oxygen are present in the same ratio as in water, that is, two atoms of hydrogen to one atom of oxygen. Thus the formula for common sugar (a carbohydrate) may be written $C_{12}H_{22}O_{11}$ or $C_{12}(H_2O)_{11}$.

Carbohydrates are found in nature and are produced by plant life. The structural, fibrous part of a plant is cellulose. The digestible portion, such as seeds, roots, and fruits, generally contains the carbohydrates *starch* and *sugar*.



Photosynthesis is a process by which plants build up, or synthesize, carbohydrates from water and carbon dioxide. What is liberated in the reaction? What causes the reaction to take place?

How are carbohydrates made? The process by which carbohydrates are made within a plant is not fully known. In the cells of the leaves of green plants is a substance called *chlorophyll*. Chlorophyll, with the energetic rays of the sun, water from the soil, and carbon dioxide from the air, causes a chemical reaction which produces carbohydrates and a release of the element oxygen. This process is known as *photosynthesis*. The formation of glucose in plants, a typical carbohydrate, is illustrated by the following equation:

$$6\ CO_2 + 6\ H_2O + \text{sunlight} + \text{chlorophyll} \longrightarrow C_6H_{12}O_6\ (\text{glucose}) + 6\ O_2 + \text{chlorophyll}$$

What are the properties of carbohydrates? Carbohydrates may be grouped in three classifications: (1) *monosaccharides*, (2) *disaccharides*, and (3) *polysaccharides*. The properties and compounds included in each classification will be discussed in order.

Monosaccharides. Monosaccharides are very soluble in water; they are crystalline, white in color, and not as sweet as ordinary sugar. They are not affected by digestive enzymes and can be absorbed into the blood stream unchanged. The three monosaccharides that we are concerned with in digestion are *glucose*, *fructose*, and *galactose*. The general formula for these monosaccharides is $C_6H_{12}O_6$. Although these three monosaccharides have the same empirical formula, their molecular structures and corresponding structural formulas are different.

Glucose ($C_6H_{12}O_6$) is called also dextrose, grape sugar, or starch sugar. It is found abundantly in various kinds of plant life, such as fruits, especially grapes, and vegetables, such as sweet corn. It occurs in the blood of all animals to the extent of 0.1 per cent. Glucose is readily digested and during certain kinds of illness may be injected directly into the blood stream as an immediate source of energy. Any excess glucose in the blood is converted into a compound called *glycogen*, which will be discussed later.

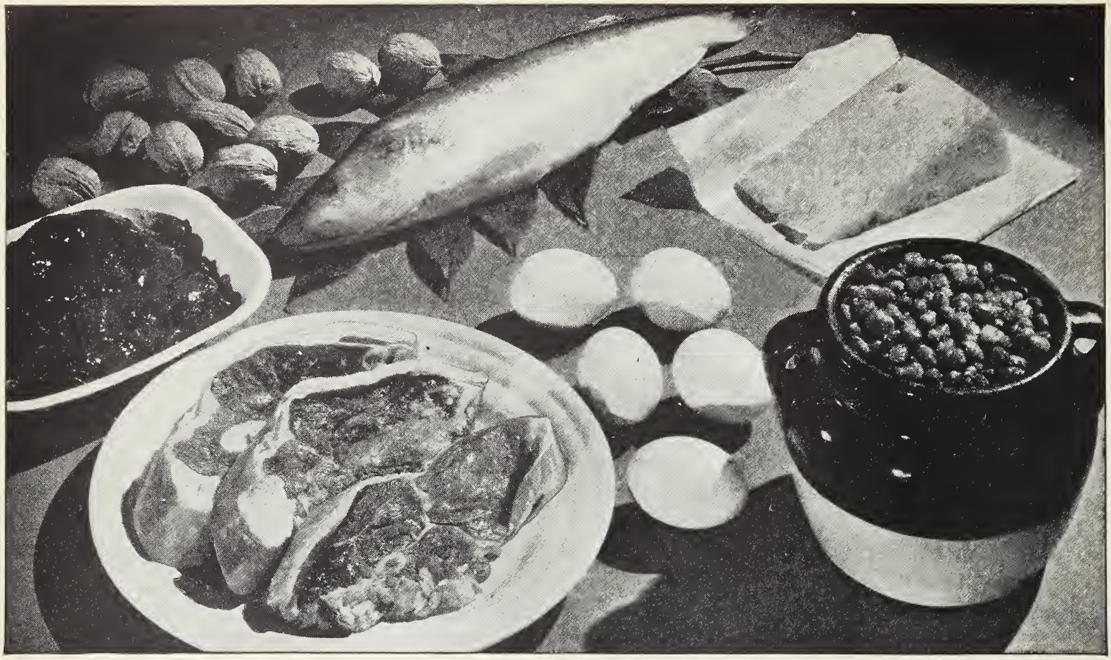
In the body glucose may be manufactured from many different carbohydrates. The artificial, or commercial, process of manufacture generally involves starch, which is treated with superheated steam in the presence of hydrochloric acid as a catalytic agent. The simplified equation for this reaction, known as hydrolysis, is

$$\overset{\text{starch}}{(C_6H_{10}O_5)_x} + x\ H_2O + HCl \longrightarrow \overset{\text{glucose}}{x\ C_6H_{12}O_6} + HCl$$

In the digestive process the body is able to duplicate this reaction. However, the body process does not necessitate superheated steam. Hydrolysis is carried on in the body through the efficient action of enzymes, which act as catalytic agents. Thus, by the hydrolysis of starch and many other carbohydrates which are found in foods, the body obtains its usable sugar.

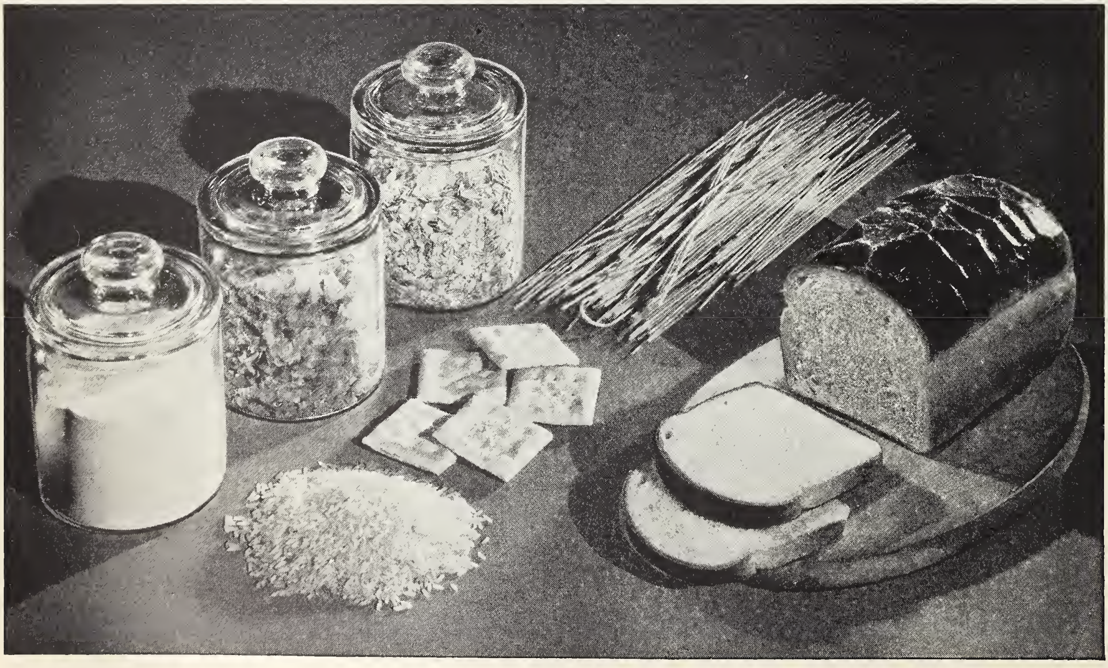
Fructose ($C_6H_{12}O_6$) is also called levulose and generally occurs with glucose in the juices of plants, in ripe fruits, and in honey. Like glucose, it may be converted into glycogen in the body.

Galactose ($C_6H_{12}O_6$) is obtained from the hydrolysis of milk sugar (lactose, $C_{12}H_{22}O_{11}$) by the



National Dairy Council

The foods above are rich in proteins; the foods below are rich in carbohydrates



action of digestive enzymes. It also may be converted into glycogen in the body.

Disaccharides. The three disaccharides to be considered in connection with digestion are *sucrose*, *lactose*, and *maltose*. Each has the formula $C_{12}H_{22}O_{11}$. These disaccharides are white in color, crystalline, soluble in water and alcohol and have a sweet taste. They char when heated, showing the presence of carbon. They constitute a very important source of food and are changed to monosaccharides in the process of digestion.

Sucrose ($C_{12}H_{22}O_{11}$), known as cane or beet sugar, is found very widely distributed in plant life. Many fruits are especially rich in sucrose content. The principal commercial sources are the sugar beet, the sugar cane, and the sugar maple. The methods used in obtaining sucrose from these sources and refining it will be discussed in connection with chemistry in industry. On hydrolysis, each molecule of sucrose yields one molecule of glucose and one of fructose. This hydrolysis takes place in the presence of either an acid or a particular kind of digestive enzyme. The equation showing this reaction is

$$\overset{\text{sucrose}}{C_{12}H_{22}O_{11}} \overset{+}{+} \overset{\text{water}}{H_2O} \overset{\longrightarrow}{\longrightarrow} \overset{\text{glucose}}{C_6H_{12}O_6} \overset{+}{+} \overset{\text{fructose}}{C_6H_{12}O_6}$$

Lactose ($C_{12}H_{22}O_{11}$), also known as milk sugar, is found in the milk of all mammals. Human milk averages about 6.5 per cent lactose and cow's milk about 4.5 per cent. Lactose is neither as sweet nor as soluble as sucrose. Hydrolysis, caused by heating with an acid or through the action of an enzyme, yields one molecule of glucose and one of galactose for every molecule of lactose. The value of milk sugar in infant-feeding comes from the fact that if it ferments in the stomach, it is not apt to cause irritation of the stomach membrane, as is many times true of fermented sucrose.

The fermentation that takes place when milk sours changes the lactose into lactic acid:

$$\begin{aligned} &\overset{\text{lactose}}{C_{12}H_{22}O_{11}} \overset{+}{+} \overset{\text{water}}{H_2O} \overset{+}{+} \overset{\text{ferment}}{\text{ferment}} \\ &\qquad\qquad \overset{\longrightarrow}{\longrightarrow} \overset{\text{lactic acid}}{4\ CH_3CHOHCOOH} \end{aligned}$$

The formation of lactic acid in the stomach aids in the precipitation of casein, commonly known as milk curd.

Maltose ($C_{12}H_{22}O_{11}$), sometimes called malt sugar, is produced by the fermentation of the starch in many different grains. In the digestive system it is produced as an intermediate product by the action of certain enzymes on starch. After formation, the maltose is acted upon by another enzyme, which splits each molecule into two molecules of glucose:

$$\overset{\text{starch}}{2(C_6H_{10}O_5)_x} \overset{+}{+} \overset{\text{enzyme}}{\text{enzyme}} \overset{+}{+} \overset{\text{water}}{x\ H_2O} \overset{\longrightarrow}{\longrightarrow} \overset{\text{maltose}}{x\ C_{12}H_{22}O_{11}}$$

$$\overset{\text{maltose}}{C_{12}H_{22}O_{11}} \overset{+}{+} \overset{\text{enzyme}}{\text{enzyme}} \overset{+}{+} \overset{\text{water}}{H_2O} \overset{\longrightarrow}{\longrightarrow} \overset{\text{glucose}}{C_6H_{12}O_6} \overset{+}{+} \overset{\text{glucose}}{C_6H_{12}O_6}$$

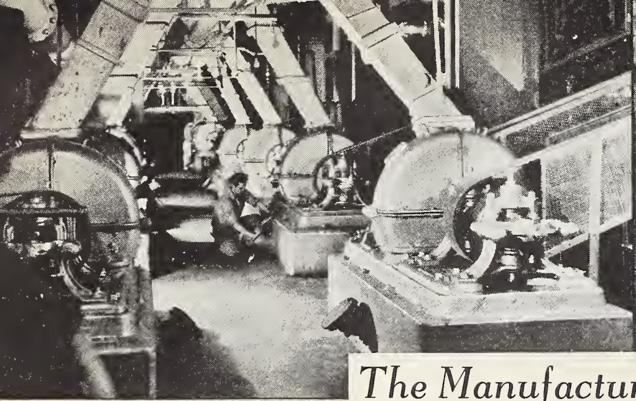
Polysaccharides. The compounds of the polysaccharide class of carbohydrates are more complex in structure than the monosaccharides and disaccharides. They are usually amorphous, have but little taste, and vary in solubility. Those which are soluble generally form colloidal solutions. A colloidal solution is one in which the particles of the solute are not broken down to the size of molecules but are small enough to remain suspended and evenly distributed throughout the solution. Some of the polysaccharides that are of great importance in digestion are *starch*, *dextrin*, *cellulose*, and *glycogen*. Each of these varies in the degree of digestibility. The formula for all polysaccharides is $(C_5H_{10}O_5)_x$. The exact structure of polysaccharides is unknown. It is known, however, that the molecule is a multiple of $C_6H_{10}O_5$. Hence an x is used to denote an unknown multiple.

Starch $(C_6H_{10}O_5)_x$ is very extensively found in plant life. It is especially abundant in seeds, bulbs, tubers, and roots. Starch is practically insoluble in cold water. Granules placed in warm or hot water absorb the water and finally form a colloidal starch paste.

Starch is readily changed into soluble sugars by hydrolysis. This process has been described as a part of the discussion of glucose. In the digestive tract the enzymes change starch first to dextrin, then to maltose, and finally to glucose. If the granules of starch are burst by heat, the starch becomes more soluble and much easier to digest.

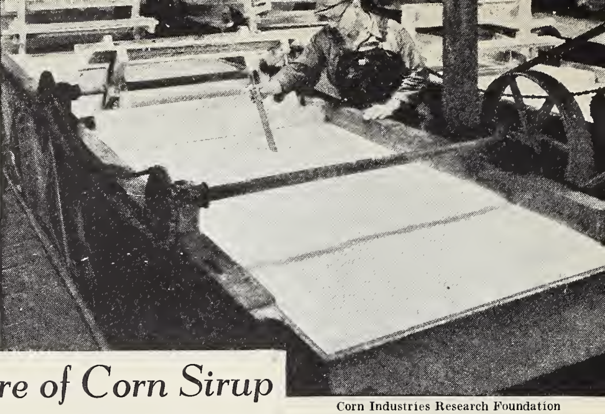
Dextrin $(C_6H_{10}O_5)_x$ may be prepared synthetically by slowly heating starch. Thus the process of baking bread makes a crust of dextrin. Likewise, hard toast contains a high percentage of dextrin.

The Manufacture of Corn Sirup



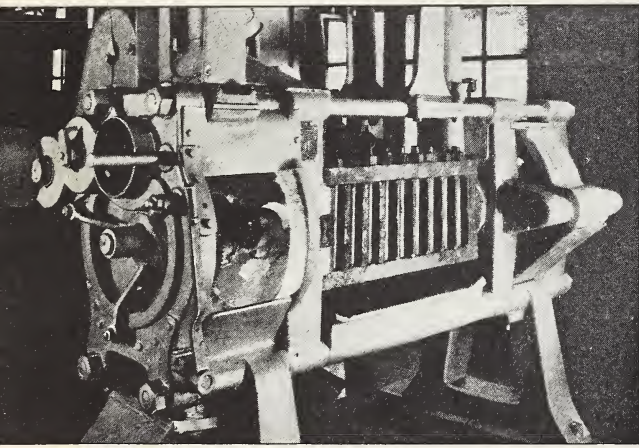
Corn Industries Research Foundation

Grains of corn are first run through these attrition mills, where the kernel is shredded by revolving plates



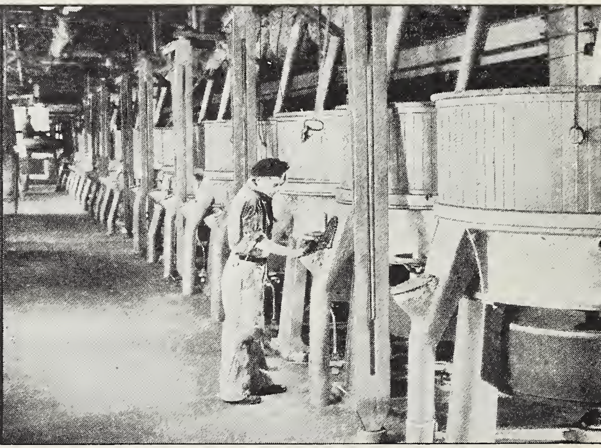
Corn Industries Research Foundation

The germ contains most of the oil, which floats to the top, to be skimmed off in these germ-separation tanks



Corn Industries Research Foundation

An oil-expeller which removes the oil from the germ of kernels of corn. This corn oil is sold as a salad and cooking oil



Corn Industries Research Foundation

After the germ has been separated, the remaining parts of the kernel are finely ground in Buhr mills

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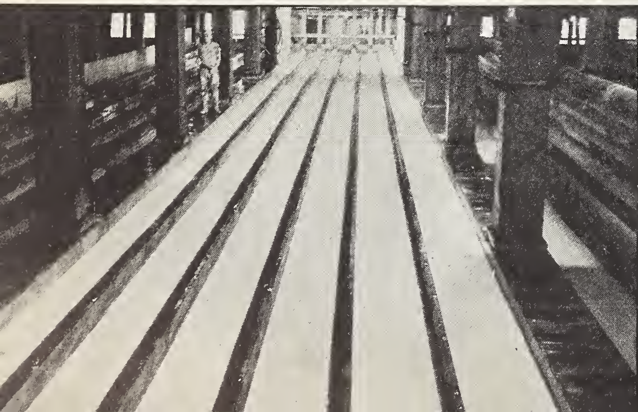
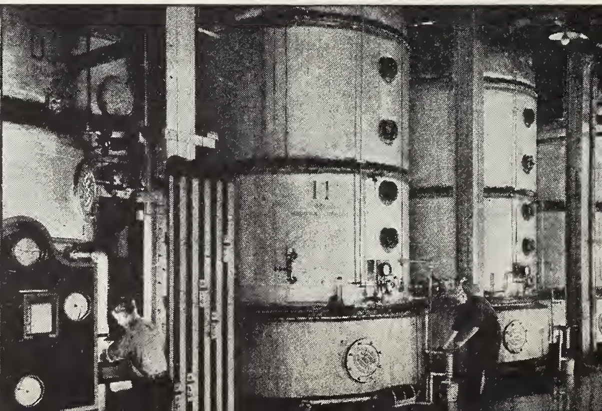
The mixture runs to starch tables, where the heavier starch sinks to the bottom and the lighter gluten floats on the top and passes over the end of the tables. The starch is then dried and packaged or is processed into dextrin, sirup, or corn sugar

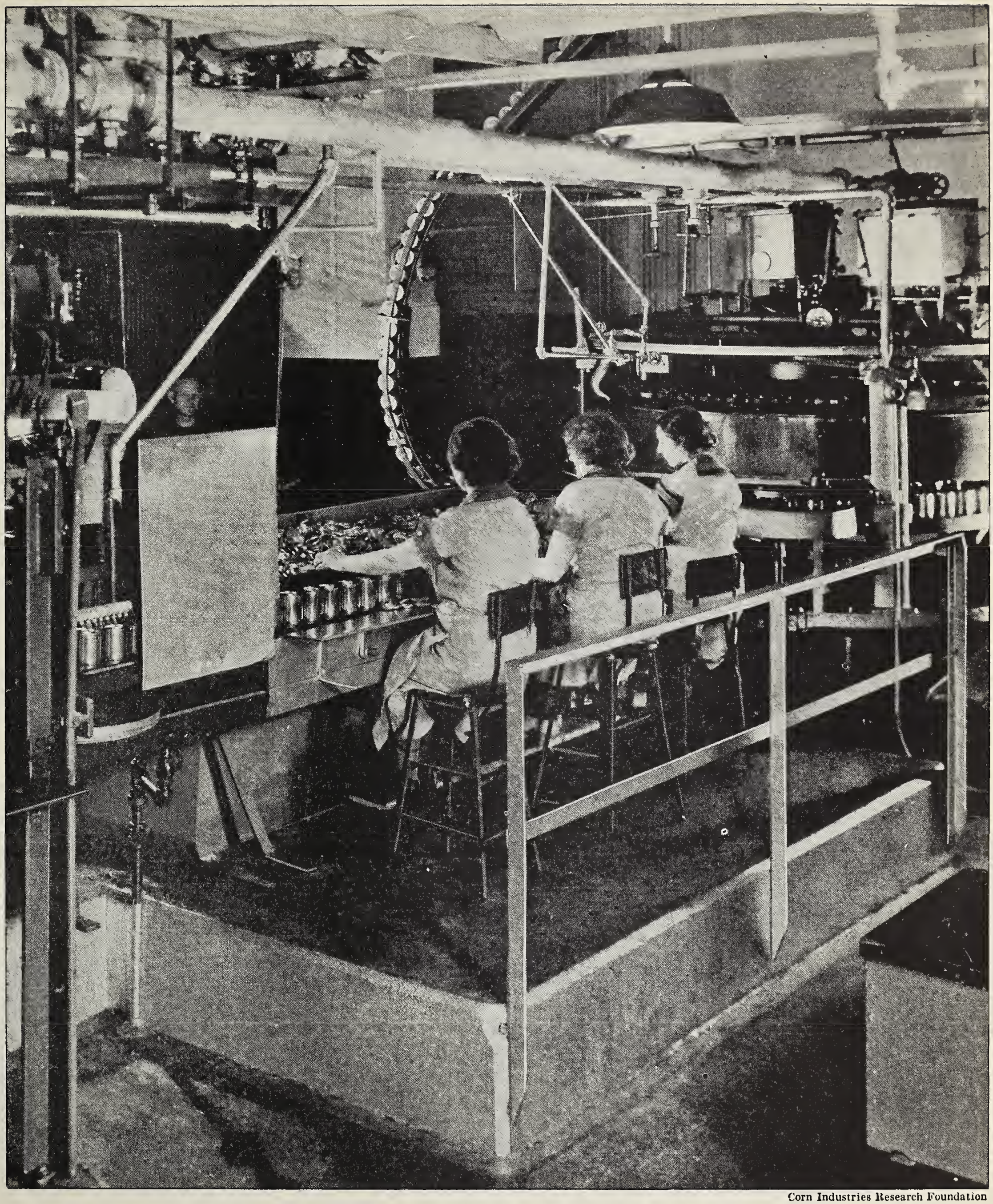
Corn Industries Research Foundation



Starch mixed with water is heated in these converters in the presence of dilute hydrochloric acid. The starch hydrolyzes to form corn sirup, a mixture of glucose (dextrose), dextrin, and maltose. The acid is neutralized with sodium carbonate

Corn Industries Research Foundation





Corn Industries Research Foundation

After passing through bone-char filters the corn sirup is canned by automatic machinery

Dextrin is much more soluble in water than starch is. It has a sweetish taste and is rather easily digested. You enjoy eating toast because it contains brown, somewhat sweet, dextrin. The final stage of its digestion is glucose.

Glycogen $(C_6H_{10}O_5)_x$, or animal starch, is the only polysaccharide made in the human body. It is found in all parts of the body and is especially abundant in the liver. The liver stores glycogen as a colloidal solution and releases it to all parts of the body as it is needed. Glycogen is a white amorphous powder which has no odor or taste; it resembles cornstarch in appearance.

Cellulose $(C_6H_{10}O_5)_x$ is the structural mass of a plant. It may be thought of as the skeleton, or support for the plant cells. Cotton fiber is almost pure cellulose. Its commercial use will be discussed later in connection with the manufacturing of paper, rayon, "Cellophane," etc.

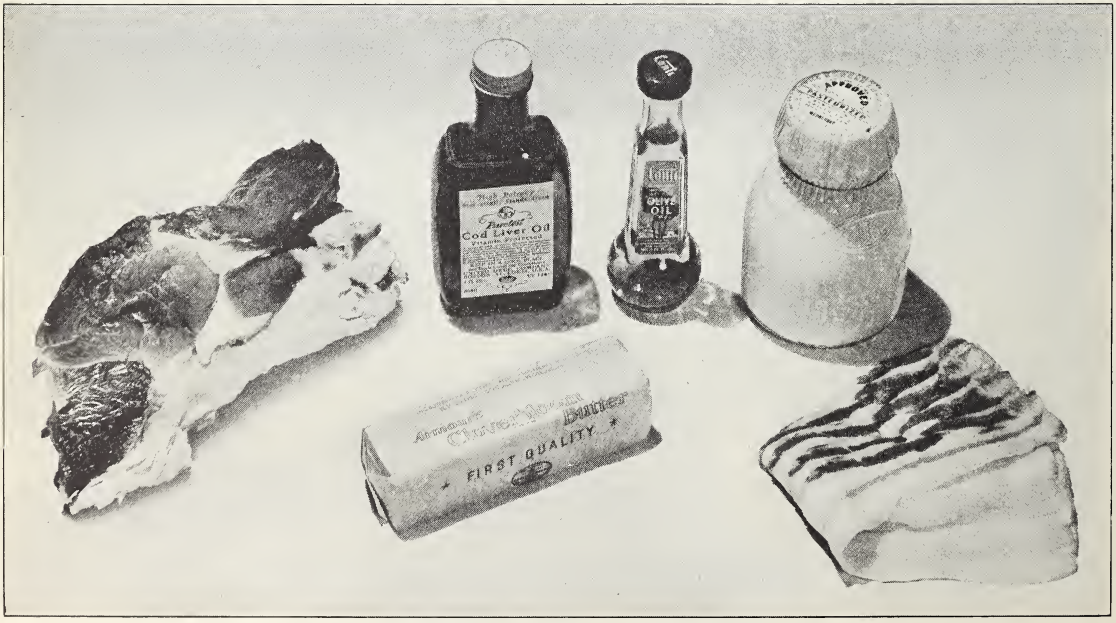
Cellulose is insoluble in water, and in the body is only very slightly digestible. Therefore we cannot rely upon cellulose as an energy-giving food. However, its importance in the complete digestive process cannot be overestimated. In order that proper elimination of waste matter may take place through the intestines, a certain amount of bulk is necessary. This bulk, most of which is supplied by cellulose, stimulates the motion of the walls of the intestines and thereby moves the waste matter to the lower bowels, from which it is expelled from the body as feces.

Fats. Fats are organic compounds composed of carbon, hydrogen, and oxygen. However, the fat molecule contains a much higher percentage of carbon and hydrogen than the carbohydrate molecule. In the language of the organic chemist, a fat is an *ester* produced by the reaction between a *fatty acid* and *glycerin*. The following equations illustrate the possible formation of several important fats:

Fatty Acid	+ Glycerin	⟶	Fat	+ Water
1. 3 $C_{15}H_{31}COOH$ palmitic acid	+ $C_3H_5(OH)_3$	⟶	$C_3H_5(C_{15}H_{31}COO)_3$ glyceryl palmitate (palmitin)	+ 3 HOH
2. 3 $C_{17}H_{33}COOH$ oleic acid	+ $C_3H_5(OH)_3$	⟶	$C_3H_5(C_{17}H_{33}COO)_3$ glyceryl oleate (olein)	+ 3 HOH
3. 3 $C_{17}H_{35}COOH$ stearic acid	+ $C_3H_5(OH)_3$	⟶	$C_3H_5(C_{17}H_{35}COO)_3$ glyceryl stearate (stearin)	+ 3 HOH

Foods rich in fats

Ewing Galloway



Fats and oils occur in the tissues of animals and plants, and from these sources man obtains the fat which he uses. Fats and vegetable oils, such as olive oil, cottonseed oil, lard, and tallow (to give them their common names), are generally mixtures of fatty esters. Thus olive oil is a mixture of about 75 per cent olein and some palmitin and stearin. Olein is a liquid fat, while palmitin and stearin account for the solid nature of various common fats, such as lard and butter. There are many other fats in addition to the three mentioned. However, these three are the ones most commonly found in foods.

The digestion of fats involves first changing the *fatty esters* to *fatty acids* and thence to *soap.*

Minerals. Estimates, based upon some experimentation, have been made of the percentage of various elements which make up the body structure. They are as follows:

Element	Approximate Percentage	Element	Approximate Percentage
Oxygen	65	Sulfur	0.25
Carbon	18	Sodium	0.15
Hydrogen	10	Chlorine	0.15
Nitrogen	3	Magnesium	0.05
Calcium	1.5	Iron	0.004
Phosphorus	1.0	Iodine	0.00004
Potassium	0.35		

There are also minute amounts of zinc, manganese, copper, fluorine, and silicon and traces of nickel, aluminum, and cobalt.

Since these elements occur in the body, it is essential that they be continually supplied to the body by the food we eat.

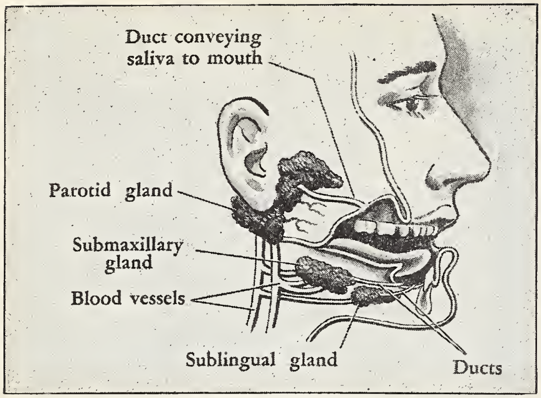
The elements oxygen, carbon, hydrogen, and nitrogen are supplied to the body through the digestion and assimilation of proteins, carbohydrates, and fats. In addition, proteins sometimes contribute sulfur, phosphorus, and iron.

The elements other than oxygen, carbon, hydrogen, and nitrogen are generally referred to as mineral elements. Although some of these elements are supplied to the body in organic compounds, most of them are in the form of inorganic salts which are present in the food. As many of these salts are soluble, they are absorbed into the blood stream after being dissolved in the digestive tract.

Vitamins. These chemical substances are the most recently discovered of the food nutrients. They are organic compounds and are known to be essential in the regulation of body processes. Vitamins are needed only in small amounts; yet the control they have over body processes is powerful. At the present time many vitamins are known to exist. The most widely known of them, in the

These foods are rich in minerals and vitamins. They are called protective foods

National Dairy Council



Saliva is secreted by the three sets of glands shown in this picture. What part does saliva play in the digestive process?[1]

order of their discovery, are A, B_1, G (or B_2), C, D, and E. Vitamins A, D, and E are soluble in fats, and vitamins B, C, and G are soluble in water.

EXERCISES

1. What elements compose protein?
2. What are the general properties of proteins?
3. Are the proteins that man eats the same as those found in his body tissue? Explain.
4. What are carbohydrates?
5. How are carbohydrates made in plants? Give the equation for the reaction.
6. Give the general formula and the characteristics of the monosaccharide carbohydrates.
7. Name and describe three common monosaccharides.
8. How is glucose manufactured? Write an equation for the reaction.
9. What is the general formula of the disaccharides? What are their properties?
10. Name three important disaccharides and tell the source of each.
11. Write the equation for the hydrolysis of each of these disaccharides.
12. What is a polysaccharide?
13. Name and give the properties and source of four important polysaccharides.
14. Of what value is cellulose in the digestive process?
15. What are fats?
16. How are fats formed?
17. Name several of the common fats.
18. What elements make up the body structure?
19. Where does the body obtain these elements?
20. What are vitamins?
21. Which vitamins are water-soluble? fat-soluble?

Problem 4. How is food digested?

Digestion dissolves food. Digestion is a chemical and physical process in which food is made soluble so that it can be used by the body. This process begins in the mouth, continues in the stomach, and is completed in the small intestine. Your knowledge of digestion will be more thorough if you trace each food nutrient as it passes through the complete digestive tract.

Digestion in the mouth. The preliminary preparation that food undergoes in the mouth is of great importance. Here the food is finely divided by chewing, and, at the same time, it is mixed with saliva and mucus secreted by glands. This action results in three essential physical changes:

1. Chewing separates food into fine particles, producing a large increase in surface, which makes for better and more nearly complete chemical action in the stomach and intestine.
2. The saliva moistens the food, which starts the process of dissolving the food and stimulates the sense of taste.
3. The mucus and saliva lubricate the food so that it can be swallowed without great effort.

In addition to these changes, the saliva contains the starch-splitting enzyme ptyalin, which first partially changes the starch to the more soluble dextrin and thence to maltose and glucose. This process is slow and never complete. However, slow and thorough chewing of the food will aid appreciably in increasing its exposed surface so that the starch will be easily accessible to the enzyme. The reaction of changing the starch to maltose can then be continued in the first section (fundus) of the stomach. Starch is the only food substance which undergoes a chemical change in the mouth.

Digestion in the stomach. After the food reaches the stomach, it is moved slowly along by muscular action to the mid-portion. In the walls of this section are located the glands that secrete the gastric juice. The gastric juice is mixed thoroughly with the semifluid mass of food through a churning motion. In this gastric juice are three enzymes: *pep-*

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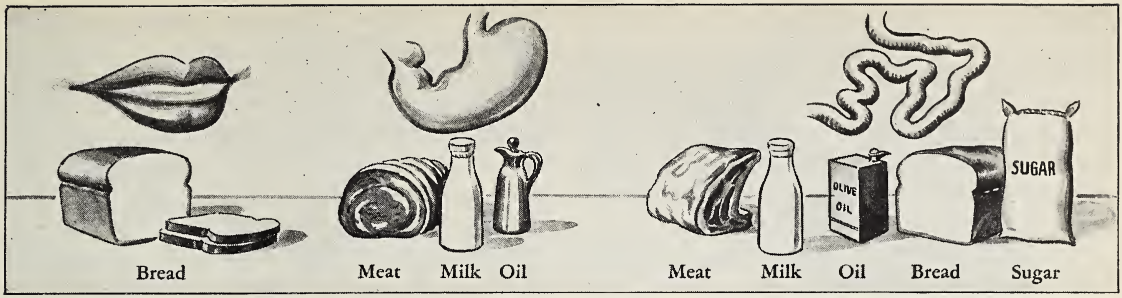
[1] Reproduced from Curtis, Caldwell, and Sherman's *Everyday Biology,* Ginn and Company.



The body has three organs of digestion: the mouth, the stomach, and the intestines. What part does each organ play in the digestion of the foods shown here?

sin, *rennin*, and *gastric lipase*. Approximately 0.3 per cent of the gastric juice is hydrochloric acid, which produces acidity of the stomach contents. (HCl is probably produced from the common table salt (NaCl), which occurs naturally in foods or has been added to them.) This acidity is essential for the action of the enzymes. The enzyme pepsin splits the protein molecules partially into compounds known as *proteoses* and *peptones*. The rennin causes milk to curdle and coagulate so that its protein may be acted upon by the pepsin.

The fat is acted upon by the *gastric lipase* and the hydrochloric acid of the gastric juice. The HCl helps to separate the fat into small globules, and at the same time provides an acid medium. The gastric lipase, which acts only in an acid solution, causes the fat to hydrolyze to a fatty acid and glycerin:

$$\overset{\text{palmitin}}{C_3H_5(C_{15}H_{31}COO)_3} \overset{+}{+} \overset{\text{water}}{3\,HOH}$$

$$\longrightarrow \overset{\text{palmitic acid}}{3\,C_{15}H_{31}COOH} \overset{+}{+} \overset{\text{glycerin}}{C_3H_5(OH)_3}$$

See if you can write the equations showing the reaction with stearin.

There is some doubt about how much fat is acted upon in the stomach. It is generally accepted that 25 per cent or less of the fat is affected.

Stomach digestion is not a rapid process. The time varies from one and a half to seven hours, depending on the kind and fineness of the food particles. It is known that carbohydrates are digested more quickly than proteins, and proteins more quickly than fats. A mixture of protein and fats is digested more slowly than other combinations of food nutrients.

Digestion in the intestine. When the food is moved by muscular movement (peristalsis) into the small intestine, the liquid bile from the gall bladder, the pancreatic juice from the pancreatic gland, and the intestinal digestive juice from the intestinal glands are poured upon it and mixed with it. These juices begin to act upon the food, already partially digested, to complete the digestive process.

Protein. The work of protein digestion is that of changing unaffected protein and the already partially digested proteoses and peptones expelled from the stomach to *soluble* amino acids. This chemical action is made possible by the enzymes *trypsin* and *erepsin*. Trypsin is supplied to the small intestine by the pancreatic juice secreted by the pancreatic gland. Erepsin is found in the intestinal juice secreted by glands located in the walls of the small intestine. Trypsin acts upon the unaffected protein, the proteoses, and the peptones, changing them partially to polypeptides and thence to *amino acids*. Erepsin also helps to bring about this change.

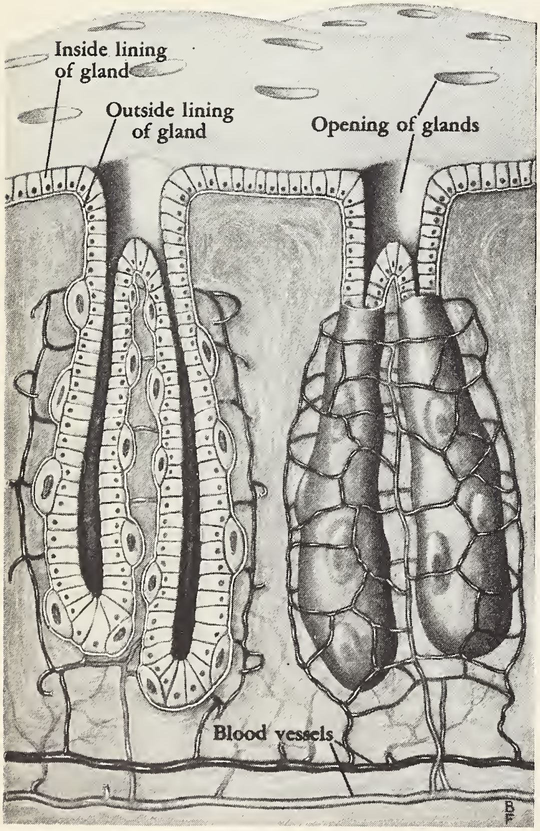
In summarizing the complete chemical action of the digestion of proteins, it is well to note that this action passes through four definite stages: (1) proteoses, (2) peptones, (3) polypeptides, and (4) amino acids. It is also interesting to know that if one of the enzymes fails to perform its function, the entire digestive action is not necessarily upset. Each enzyme, except rennin, can carry on more than one of the stages of digestion. Protein could pass through the stomach without being affected chemically, and yet the digestion would be carried on in the small intestine. Trypsin is capable of carrying on complete digestion by itself.

Carbohydrates. In the small intestine the process of changing all food carbohydrates into the simple sugar *glucose* is completed. The enzyme amylopsin, from the pancreatic juice, changes the unaffected starch and dextrin to maltose. The intestinal juice, which contains the enzyme maltase, changes the maltose to glucose; the enzyme sucrase converts the sucrose to glucose; and the enzyme lactase changes the lactose to glucose. *As a final result, we find that all carbohydrates, except cellulose, are converted to the simple monosaccharide sugar glucose.*

Fats. The bile from the gall bladder, which is also poured into the small intestine, plays an important role in the digestion of fats. Its function is that of breaking the fat into small globules and acting as a solvent for the fat which is not digested in the stomach. With the fat in small particles and partially dissolved, the enzyme *steapsin* in the intestinal juice continues the process of hydrolysis of the fats to fatty acids and glycerin. This reaction is similar to that produced by the gastric lipases. The fatty acids are not soluble in water, and before they can be absorbed into the blood stream, they must be changed to soluble compounds. The process of changing the fatty acids to soluble substances which will pass through the intestinal wall is not completely understood. Most authorities believe that alkali salts, which originally came from the food, react with the fatty acids to form soluble soap. For the purpose of providing an illustrative equation showing the formation of soap, let us assume that the alkali salt is sodium carbonate, thus:

$$\overset{\text{palmitic acid}}{2\,C_{15}H_{31}COOH} + \overset{\text{sodium carbonate}}{Na_2CO_3} \longrightarrow \overset{\text{soap}}{2\,C_{15}H_{31}COONa} + \overset{\text{water}}{H_2O} + \overset{\text{carbon dioxide}}{CO_2}$$

Proteins are partially digested by the juices secreted by these glands in the stomach[1]



This equation illustrates the final conversion of all fats so that they may be absorbed.

From 85 per cent to 95 per cent of the proteins, digestible carbohydrates, and fats which are eaten are digested. The undigested food, including the cellulose, passes from the small into the large intestine. This food is acted upon by intestinal bacteria which cause putrefaction, and it is then excreted from the body.

EXERCISES

1. Describe the digestion which takes place in the mouth.

2. Explain fully the digestion which takes place in the stomach.

3. How long does food remain in the stomach?

4. Give a full explanation of the digestion of proteins, carbohydrates, and fats as it takes place in the intestine.

Problem 5. How is food absorbed and used in the body?

The absorption and use of proteins. Amino acids, the final digestive products of proteins, pass into the blood stream through the villi, which are small projections from the walls of the small intestine. The blood carries these acids to the liver, which in turn distributes them to all parts of the body, where they are absorbed into the tissues.

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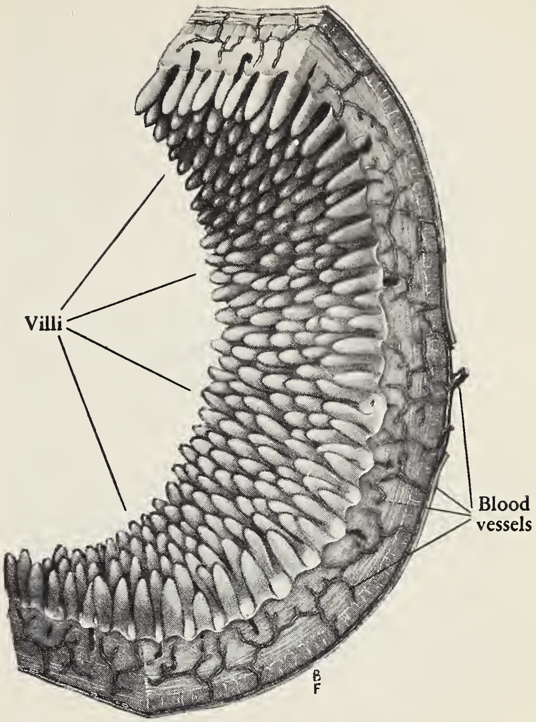
[1] From Powers, Neuner, Bruner, and Bradley's *Our World Changes*, Ginn and Company.

The cells of each kind of tissue, in receiving these amino acids, must perform the chemical duty of changing the acids back to protein. This resynthesized, or rebuilt, protein is always identical with that which makes up the particular tissue which is producing it. Each tissue makes its own protein. Thus muscle tissue requires a particular kind of protein, and nerve tissue requires another kind. However, not all the amino acids are used for building and repairing the tissues. The acids not used for these purposes may be converted into glucose (a carbohydrate), which is then used to produce energy through the process of oxidation, or may be resynthesized into fat. The conversion to glucose is made possible by the "splitting off" of the nitrogen part of the amino acids. This chemical action is performed by the cells. The product resulting from the nitrogen part of the amino acids is urea ($NH_2 \cdot CO \cdot NH_2$), which is carried by the blood to the kidneys, where it is excreted in the urine. A small amount is also excreted in the perspiration. In the body it is estimated that about 58 per cent of the digested proteins are changed to glucose, while 42 per cent are resynthesized to protein tissue.

In summarizing the use of proteins in the body, you should bear in mind that the principal values are those of the *building of new tissues* and the *maintaining of tissues already built*. While proteins may be used for fuel, under normal conditions two other nutrients, fats and carbohydrates, are capable of supplying all the energy needed by the body. In addition, this method of producing energy by proteins is generally considered inferior, owing to the fact that the waste products of the oxidation are hard to eliminate and place an added burden on the kidneys.



These tiny fingers, which line the inside of the small intestine, absorb the digested food[1]

The conditions of life which determine the proteins we need. During the life span of any normal person, the amount of proteins required by the body varies with his age, size, sex, and physical condition. In childhood, when the body is growing and new tissue of all kinds is being built, the protein requirement is relatively high. For this reason, it is necessary that the diet of a growing child include sufficient protein. As the growing becomes less rapid, smaller amounts of protein are necessary. Obviously, the protein requirement will vary with a person's size. During the period of pregnancy, when a new body is being built, the protein requirement for women is great. This requirement continues to be high during the period of nursing, or lactation. Since illness is always accompanied by the destruction of tissue, the period of convalescence demands a diet rich in protein to rebuild impaired tissue.

The body is very similar to a machine in that it requires a certain amount of upkeep after it is built. The protein required for this purpose is not necessarily large, but the amount is in constant demand and is called the *basal diet requirement*. It should be recalled that the body needs proteins which are digestible into some twenty-two amino acids. Some proteins will not produce these twenty-two acids and are therefore said to be *incomplete*. Hence the protein diet should be varied so as to include all these acids. We cannot assume that everyone has

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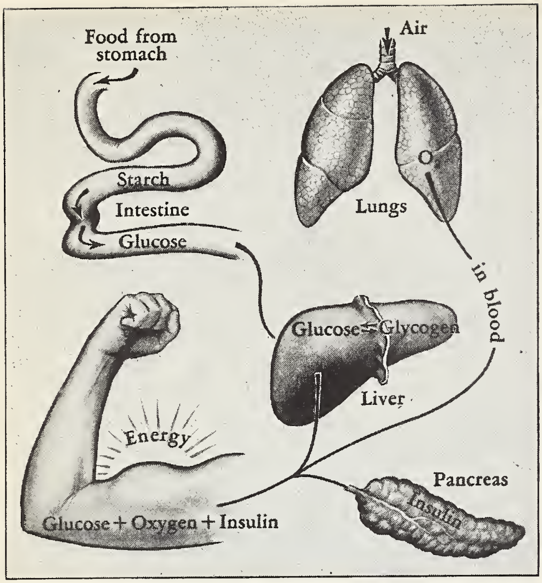
[1] From Powers, Neuner, Bruner, and Bradley's *Our World Changes*, Ginn and Company.



Glucose is absorbed into the blood stream and carried to the liver, where it is converted into glycogen and stored. When any part of the body needs energy, the glycogen is converted into glucose, which is carried to the cells of that part of the body. In the cells the glucose is burned with oxygen, in the presence of insulin, to produce energy. What part does insulin play in this reaction?

the same completeness of digestion and absorption; consequently there will be a variation in the protein requirement for each individual.

How much protein does the body require? In discussing the amount of protein the body requires, it is necessary to realize that the body will always use more protein than is actually needed. The actual protein need of the body for the building, maintenance, and repair of tissue is known as the basal requirement. Any excess protein is broken down into glucose and urea.

Protein cannot be stored in the body. Protein must be manufactured within the body as needed. From this fact it is evident that the eating of large quantities of protein-rich foods at one time, and then desisting for an extended period, will not supply the constant needs of the body.

If the body is supplied with sufficient carbohydrates and fats for fuel, the amount of protein actually required can be reasonably estimated. Most authorities estimate that an average adult needs about $1\frac{1}{2}$ ounces of protein per day for each 50 pounds of weight. The average adult consumes about two or three times this amount.

Upon first examination, it will seem that this requirement is unusually small in comparison with the amount of food we eat. An inspection of the composition of food will show you that even the protein-rich foods do not, as a rule, contain high percentages of protein. For instance, lean beef contains only about 22 per cent of pure protein. By referring to the table on page 167 you will be able to learn the percentages of protein in many of the common foods.

The body is usually capable of adjusting itself to any reasonable increase in protein consumption. On the other hand, a deficiency cannot be compensated for. Not one of the other food nutrients is capable of building, repairing, or maintaining the tissues of the body.

Let us suppose that your diet is high in protein-rich foods, but below the minimum requirement of foods that produce energy. In order to meet the fuel requirement, the body would almost immediately become adjusted to changing the excess protein to glucose. This glucose would then be oxidized to supply the deficiency in energy.

The absorption and use of carbohydrates. The food carbohydrates, after being converted in the digestive process to glucose, pass readily through the intestinal walls into the blood stream and thence to the portal vein, which conducts the food directly to the liver. Although the glucose content of the blood in the general circulatory system remains fairly constant at 0.1 per cent, the blood in the portal vein contains several times this amount. This is especially true after one partakes of a meal rich in carbohydrates. In order to maintain this constant glucose content, the excess amount of glucose, above that which is oxidized, is stored in the liver cells after being changed to glycogen, or animal starch. The glycogen content of the liver may at times be equal to as much as 15 per cent of its weight, while at other times it will be less than 1 per cent. Under normal conditions, the glucose that is produced from one meal and is stored as glycogen in the liver will be used before the next meal. The liver, then, stores excess glucose as glycogen and releases it to the circulatory system as needed.

The actual use of glucose in producing energy is accomplished by insulin, a chemical substance secreted by a part of the pancreatic gland. Insulin acts as a catalytic agent to cause the oxidation of glucose. The burning, or oxidation, of glucose which takes place in the cells of the body may be represented by the following equation:

$$C_6H_{12}O_6 + 6\ O_2 + \text{insulin} \longrightarrow 6\ CO_2 + 6\ H_2O + \text{insulin} + \text{heat energy}$$

The oxidation of each molecule of glucose requires six molecules of oxygen. During the study of oxygen you learned how this oxygen is supplied to the cells so that the oxidation of food may occur.

Any excess glucose which is not oxidized or stored in the liver is synthesized into fat. The chemical action which causes this reaction is much too complicated to discuss here. It is, however, well to remember that body fat can be and is produced from carbohydrate foods.

It is estimated that carbohydrates, changed in the body to glucose, supply about three fourths of the body energy.

The absorption and use of fats. The fats which have been made soluble through the digestive process in the intestine do not pass directly into the blood stream, as the soluble proteins and carbohydrates do. Small projections upon the inner walls of the intestine, called villi, have ducts which conduct the digested fat materials (soap and glycerin) to the lymph vessels. As the soap and glycerin pass through these ducts, they are resynthesized into fat, which is carried by the lymph vessels to the thoracic duct, from which it is poured into the blood stream. The mechanism that produces this rebuilding of fat is not known. It is interesting to know that the resynthesized fat is always chemically the same fat as that which was eaten. The only purpose served by changing the fat to soap is to render it soluble, so that it will pass through the intestinal walls.

Fats that are provided to the cells of the tissue may either be oxidized to produce energy or be stored as a part of the tissue. The amount that is burned depends upon the requirements of the body at that particular time. Whether the stored fat will remain as such and accumulate is determined by the amount of food consumed compared with the total body requirement. If we take less food into the body than is actually required for energy, then the deposited fat will be burned to make up for the deficiency.

National Dairy Council

These foods are rich in minerals

The use of mineral salts in the body. The table on page 145, showing the mineral content of the body, is convincing evidence that the body needs and uses minerals. The need for mineral salts in the body is based upon two uses, which have been previously stated: (1) to build, maintain, and rebuild tissue and (2) to regulate body processes. Let us discuss in detail each of these functions.

Mineral salts build and maintain tissue. Every cell of the body contains at least small amounts of mineral elements. Some of the tissue cells contain these minerals in large amounts because the elements of these minerals are very important in the building and maintenance of the tissue. Thus calcium and phosphorus are concentrated in the bones and teeth, iron in the blood, and iodine in the thyroid gland.

The body is not well equipped to store mineral salts, and there is a constant loss of from 20 to 30 grams per day, through both the urine and the feces. It is, therefore, essential that a continuous supply of minerals be provided each day to take the place of the amount lost through excretions. Each of the mineral elements will be discussed after we learn how mineral salts regulate body processes.

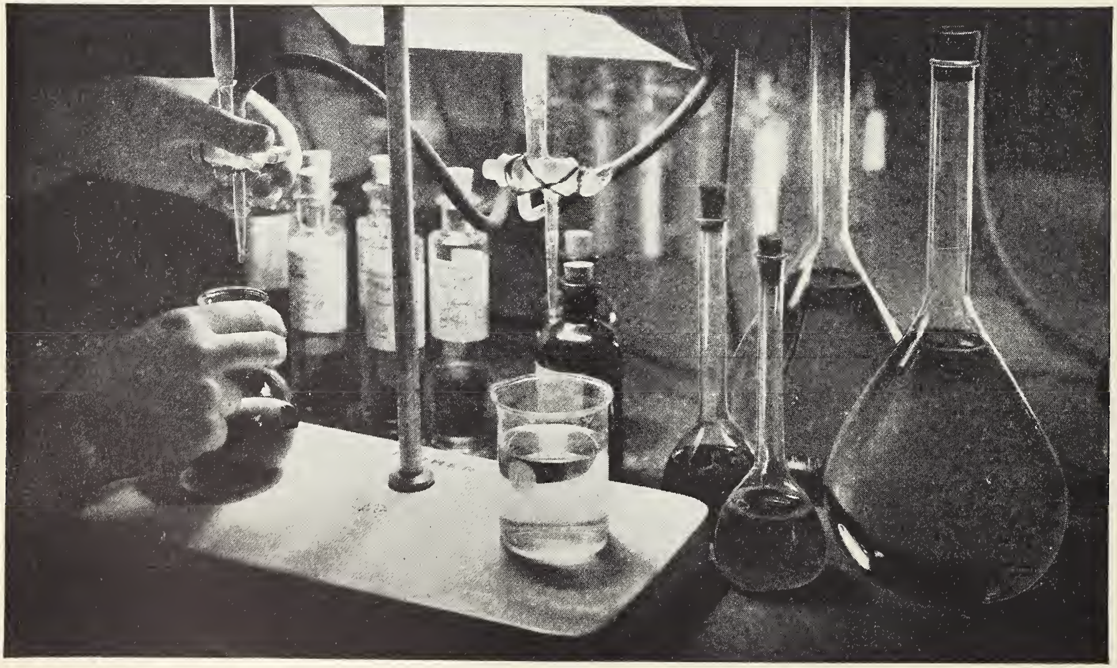
Mineral salts regulate body processes. The movement of water from one body tissue to another is regulated by mineral salts. If one part of the body tissue happens to contain too much of mineral salts, water will move from some surrounding tissue so that the percentage of salt will be equalized. In other words, each different kind of tissue in the body requires a certain concentration of particular mineral salts. If this concentration becomes greater than the requirement, water will move to the tissue, dilute the salt, and carry away the excess.

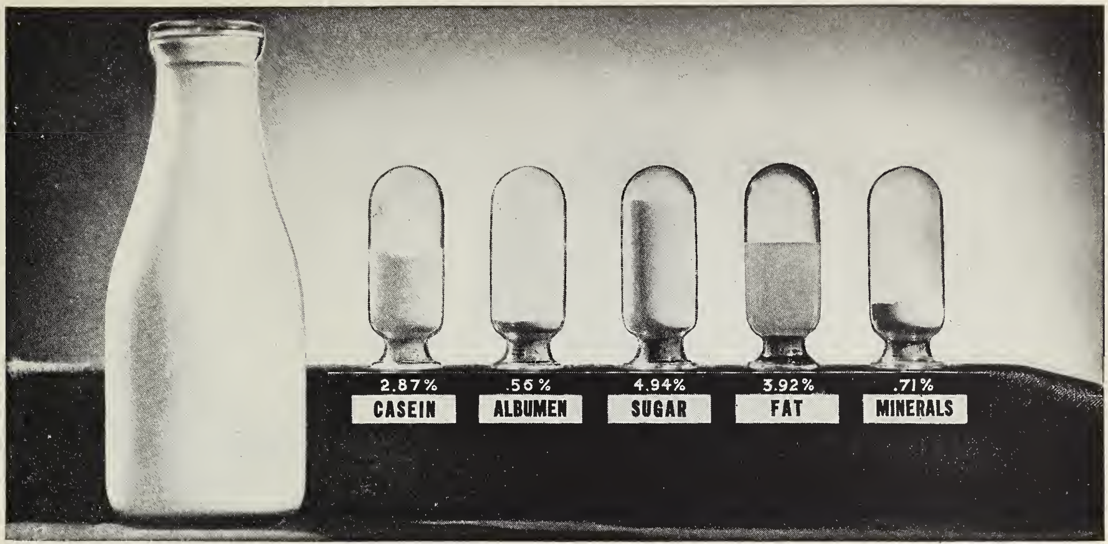
In order to work properly, the nerve and muscle tissue must have plenty of water in which is present the right amount of salts of calcium, potassium, magnesium, and sodium. An excess of calcium salts stimulates the muscle and nerve tissue, while an excess of potassium, magnesium, and sodium salts tends to retard muscle and nerve activity. Improper amounts of calcium salts may cause the muscles to contract spasmodically and may produce an irritated condition of the nerves. The entire body requires a correct concentration of mineral salts. Some mineral elements are very essential in the control of the oxidation of food within the body. For example, iron in the hemoglobin of the blood is necessary for carrying the oxygen to the cells, and the secretion of the thyroid gland contains the element iodine, which regulates the rate of oxidation.

A great deal could be said about the acid-base balance of the body. The body tissues are normally slightly basic, and there is little possibility that they will ever become acidic. It is true, however, that an overabundance of foods which are acid-forming will have a tendency to reduce this alkaline reserve of the body tissue. Such a condition is known to be unfavorable to a healthy body.

The acidity of the contents of the stomach may be determined by a laboratory technician by means of a process called titration. The exact amount of a standard base needed to neutralize the acid of a definite volume of a sample of the contents of the stomach is run into the sample, and from this amount the acidity of the stomach is determined

Colgate-Palmolive-Peet





National Dairy Council

The amounts of various food constituents contained in a quart of milk

The radio and other means of advertising have greatly overemphasized the danger of an acid diet. Some statements have tended to make the public believe that such a diet is responsible for everything from nervous ailments to skin rashes. Diets which are acid-forming will produce no ill effects if used for a moderate length of time, but may prove harmful if continued for a long period.

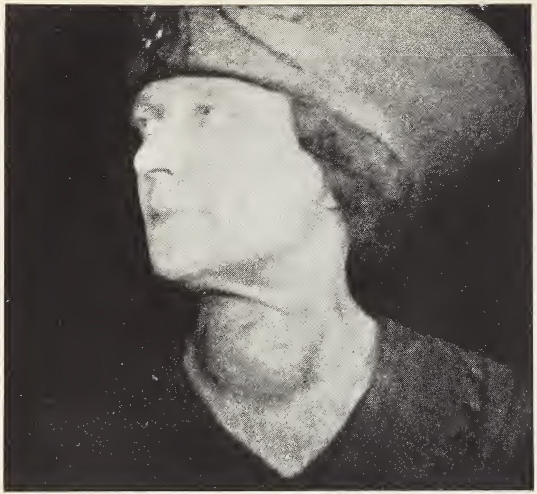
The most common acid-forming foods are eggs, meats, and cereal products. Such foods are rich in proteins, sulfur, and phosphorus. The oxidation of sulfur and phosphorus in the body produces sulfuric and phosphoric acids, which, in turn, will tend to neutralize the basic elements and thereby reduce the alkaline reserve.

The most common base-forming foods are fruits, vegetables, and milk. Even citrus fruits, which contain citric acid, produce a basic reaction when they are finally assimilated in the body. Such foods as sugar and fat are neutral foods. It is generally agreed that, except for abnormal conditions of the body, a well-balanced diet will assure one of the proper acid-base balance.

The preceding discussion has attempted to explain to you the need of the body for mineral salts. Let us now select the more important mineral elements and discuss the value, requirement, and source of each.

Calcium and phosphorus. Most of the calcium and phosphorus of the body is found in the bones and teeth. Proper amounts of these two elements are necessary to maintain the strength and rigidity of bone and tooth structure. Insufficient amounts of these two elements in the daily diet may result in tooth decay and the disease rickets. Rickets, which will be discussed in some detail in connection with vitamins, is recognized by bone deformities such as knock-knees and bowlegs.

Although the body requires less than a gram of calcium per day (an average of half a gram for a hundred-and-fifty-pound man), the danger of its possible deficiency in the diet is probably greater than the danger of a deficiency of any other mineral element. As a builder of bones and teeth, calcium is naturally required in greater amount during the period of growth and during pregnancy. Since a child's teeth are formed during the period of pregnancy, the child may be born with poorly formed teeth if the mother's diet is lacking in calcium and phosphorus. It is, therefore, essential that an expectant mother select a diet rich in calcium and phosphorus. For a growing child a quart of milk per day will more than supply the calcium and phosphorus requirement; for an adult a pint is sufficient.



Jackson Clinic, Madison, Wisconsin

Endemic goiter

Other foods rich in calcium and phosphorus are cheese, egg yolk, dried beans, and green vegetables.

Iron and copper. These two elements seem to work together in the production of the hemoglobin (red coloring matter) of the blood. You have previously learned that hemoglobin is the vehicle through which oxygen is carried to the body tissue. Any deficiency of iron and copper in the diet, then, will be accompanied by a corresponding decrease in the amount of hemoglobin. It follows that a decrease in hemoglobin will result in a decrease in the amount of oxygen carried to the body tissue. Such a condition results in what is known as nutritional anemia. A diet abundant in iron and copper will usually cure this type of anemia.

Another type of anemia is due to the production of an insufficient number of red corpuscles in the bone marrow to replace the natural destruction of these red cells. This type, called pernicious anemia, cannot be cured merely by a diet abundant in iron and copper. Other factors which affect the manufacture of red corpuscles must be taken into consideration. This disease is so serious that it requires the immediate attention of a physician.

The body does not need much iron, but what it does require is of the utmost importance. The entire body contains but 2 or 3 grams of iron, and the daily requirement is probably less than .015 of a gram.

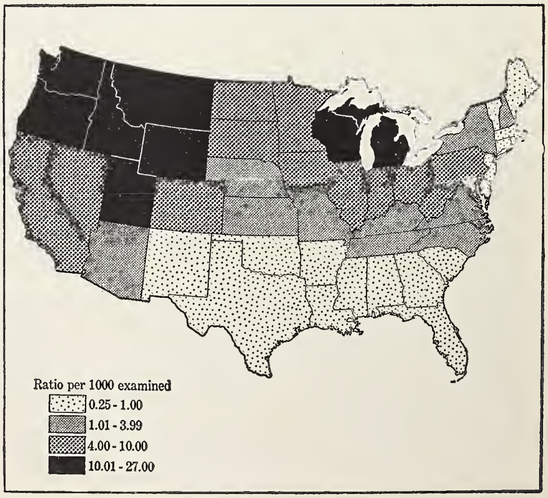
Foods rich in iron and copper are leafy vegetables, egg yolk, dried beans, and liver. These foods should be regularly included in the diet.

Iodine. The thyroid gland manufactures a secretion called thyroxine. The element iodine is essential in the manufacturing of this secretion because it is a necessary constituent of thyroxine. If the diet does not supply sufficient iodine, the thyroid gland becomes enlarged, which generally results in simple goiter.

The principal sources of iodine in the diet seem to be water that contains iodine and food which has grown in soil where the water contains iodine. The fact that sea water contains comparatively large amounts of iodine is the reason why people living on the seacoast rarely have goiter. Their drinking water contains sufficient iodine, and fish and other foods containing iodine are readily available.

Certain sections of the United States are known as goiter regions because of the iodine deficiency in the water. This is especially true of the Great Lakes region, where goiter is rather a prevalent disease. In order to compensate for this iodine deficiency, people living in these localities are urged to use iodized salt and eat fruit and vegetables grown in nongoitrous regions. Iodized salt is made by mixing common table salt with about .02 per cent sodium iodide or potassium iodide.

This map shows the regions in the United States where goiter is most prevalent



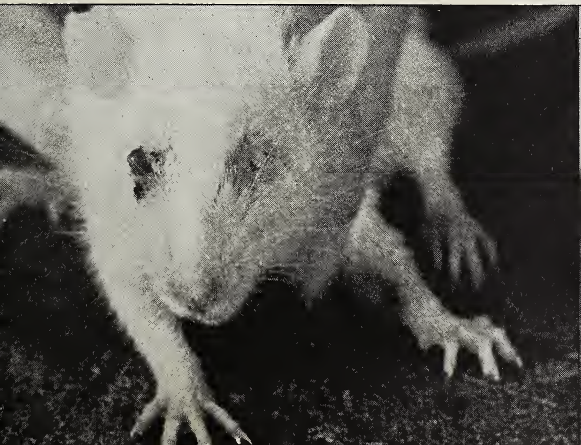
National Dairy Council

These foods are rich in vitamin A

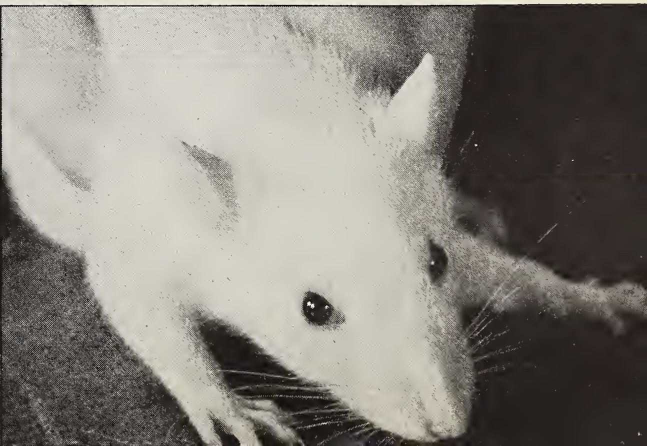
The use of vitamins in the body. The body could be supplied with all the necessary proteins, carbohydrates, fats, and minerals, and yet life would not be sustained for any length of time. It has been discovered that a group of food substances called vitamins are essential to healthful living. Vitamins are necessary for three reasons: (1) for the maintenance of general health, (2) for normal growth, and (3) for promoting reproduction and lactation. As each vitamin is presented, see how these needs are satisfied. You should notice that each vitamin is either soluble in oil and fats or soluble in water. Certain vitamins will dissolve, at least partially, in the water or the fat in which the food is cooked; to throw away the liquid from cooked foods may mean a loss of vitamin content.

Vitamin A (soluble in fats). This vitamin, which is generally considered to be an alcohol, has the formula $C_{20}H_{29}OH$. Experimentation has proved that it is generally supplied to the body by green and yellow vegetables. These vegetables contain a substance called carotene ($C_{40}H_{56}$), which is manufactured into vitamin A in the body. The vitamin, if manufactured in excess, is stored in the liver or the fat of animals. Thus a rich source of vitamin A is obtained for human consumption by extracting the oil from the liver of certain fish. You are probably aware of the use of halibut-liver oil and cod-liver oil as a rich source of vitamin A.

Carotene is known as the precursor (that is, forerunner) of vitamin A or as provitamin A. This means that when carotene gets into the body, it is



Typical eye condition produced by lack of vitamin A in the diet



Eye restored to normal by feeding vitamin A

E. R. Squibb and Sons

National Dairy Council

These foods are rich in vitamin B$_1$ (thiamine)

manufactured into vitamin A. The yellow color of carrots is due to the presence of carotene. Many green vegetables also contain carotene, but the color is masked by the green chlorophyll.

Pure vitamin A is a thick, slightly yellow oil which is decomposed by prolonged heating and oxidation. However, ordinary cooking and canning processes do not destroy it.

Vitamin A promotes growth, aids in clearing up skin blemishes, and helps to protect the body against disease-producing micro-organisms.

The latest information tends to show that vitamin A is not a substance which will directly prevent infection, but if present in the diet in sufficient amounts, it will keep the skin and mucous membranes in good health so that disease-producing microorganisms will not have favorable conditions for growth.

Continuous lack of vitamin A in the diet often results in pulmonary diseases, susceptibility to infection, and an eye disease called night blindness or xerophthalmia. Vitamin A is many times referred to as the antiophthalmic vitamin.

The principal sources of this vitamin are fish-liver oils, liver, egg yolk, leafy vegetables, carrots, butter, cheese, and whole milk. Everyone, especially growing boys and girls, should eat liberal amounts of at least two or three of these foods each day to be assured of the proper amount of vitamin A for a healthy body.

Prolonged deficiency of vitamin B$_1$ checks growth and results in degenerative changes in the nervous system

E. R. Squibb and Sons

The animal in the picture to the left was cured by feeding a food rich in vitamin B$_1$

National Dairy Council

These foods are rich in vitamin B_2, or G

Vitamin B complex (water soluble). The original vitamin B is now known to include more than one vitamin factor and is usually referred to as the vitamin B complex. At least ten factors are known to exist as parts of the vitamin B complex. The most widely known of these are B_1 (thiamine), G, or B_2 (riboflavin), B_6, pantothenic acid, and nicotinic acid. Little is known about the function of some of these factors. In the discussion which follows, the most recent information is provided.

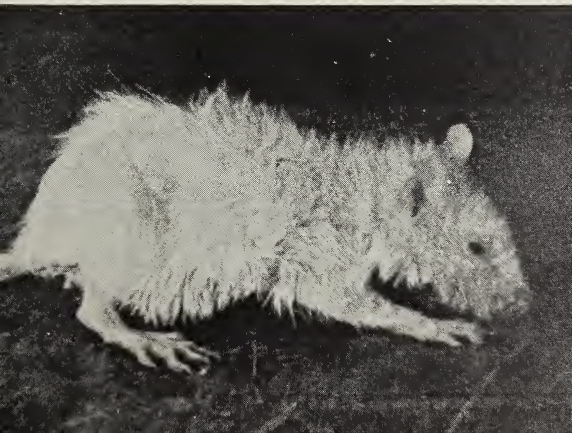
Vitamin B_1 (thiamine). If a person is deprived of this vitamin in his diet for a long period of time, a disease of the nervous system results which is called beriberi. This disease causes a breakdown of the nerves which control sensation and motion, and in extreme cases paralysis may result. The discovery of vitamin B_1 was made possible through a study of this disease. Soldiers who were fed polished rice contracted the disease, while those who were fed unpolished rice were practically free from it. A study of this case revealed that a deficiency of vitamin B_1, which is present in the hull of unpolished rice, was the cause of beriberi.

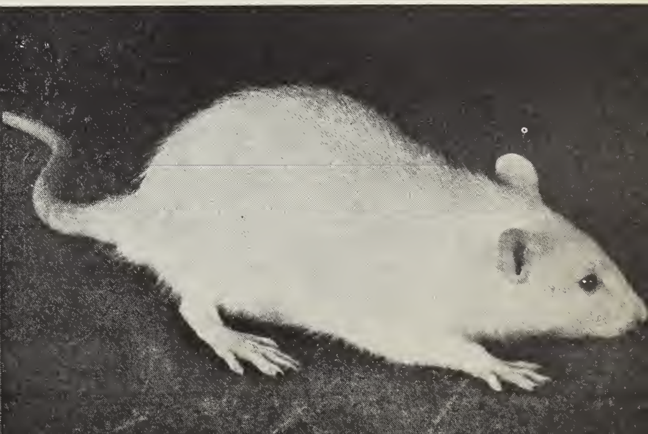
Vitamin B_1 seems to have some effect on the metabolism of carbohydrates. It also has the function of promoting muscular action of the stomach and intestines, and a deficiency of this vitamin may slow down digestion and possibly cause constipation. Lack of vitamin B_1 is generally accompanied by loss of appetite. Because of its effect upon the nervous system, it is called the antineuritic vitamin.

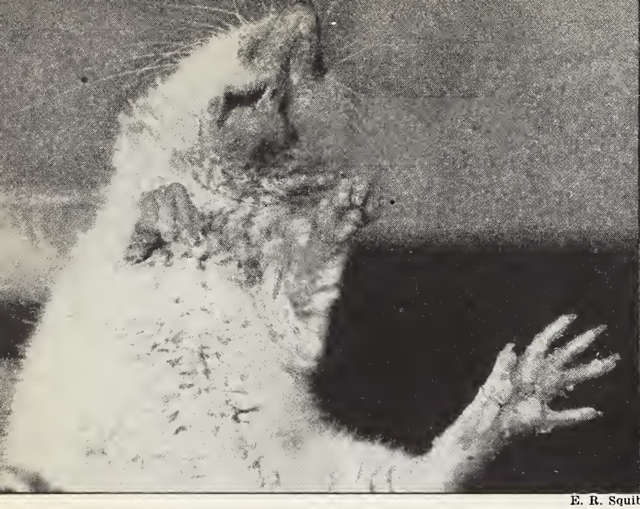
A deficiency of vitamin B_2 (G) (riboflavin) affects growth and also induces certain changes in the skin

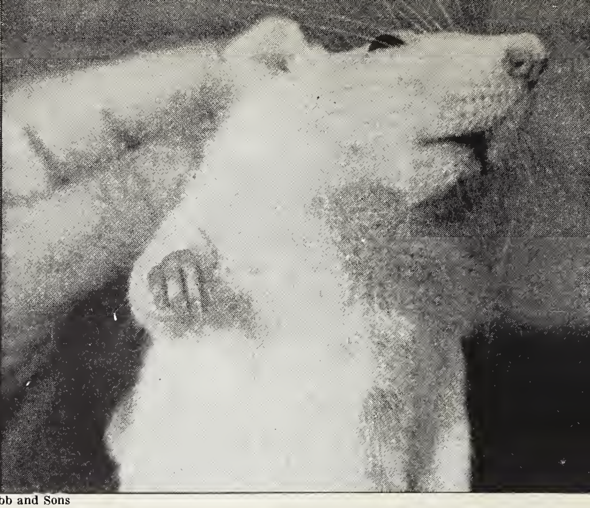
Abnormalities due to riboflavin, or B_2, deficiency cured. This vitamin was administered daily to the rat

E. R. Squibb and Sons









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Typical dermatitis (a disease of the skin) about the nose and paws due to a lack of vitamin B_6

The animal to the left was cured of disease due to vitamin B_6 deficiency by a daily dose of that vitamin

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Vitamin B_1 is widely distributed and found in many foods, but its best sources are yeast, whole-wheat bread, cereals, and fresh vegetables. It is destroyed by heating with baking soda; and since it is soluble in water, there is danger of its being thrown away with the water in which food is cooked.

Vitamin G, or B_2 (riboflavin). Until recently vitamin G was thought to prevent the disease pellagra and was known as the antipellagra factor. However, recent research has determined that the original vitamin G contains two vitamin factors, riboflavin and nicotinic acid. The antipellagra factor is now known to be nicotinic acid.

Although all the functions of vitamin G, or riboflavin, have not been completely determined, it is known that this vitamin has some control over the oxidation process within the body cells. In addition, an excess amount of this vitamin above diet requirements is thought to result in better health and vigor. Such conditions as poor general health, eye disease, and loss of hair may be attributed to a deficiency of riboflavin.

The most important sources of this vitamin are milk, yeast, liver, eggs, lean meat, peas and beans, cheese, and green leafy vegetables. These foods are, in general, also good sources of vitamin B_1.

Vitamin B_6. Although the physiological function of vitamin B_6 is not definitely known, recent research seems to indicate that this vitamin is of value in maintaining a healthy skin. When rats were fed a

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Pellagra in human beings has been attributed to diets composed of foods supplying an insufficient amount of nicotinic acid

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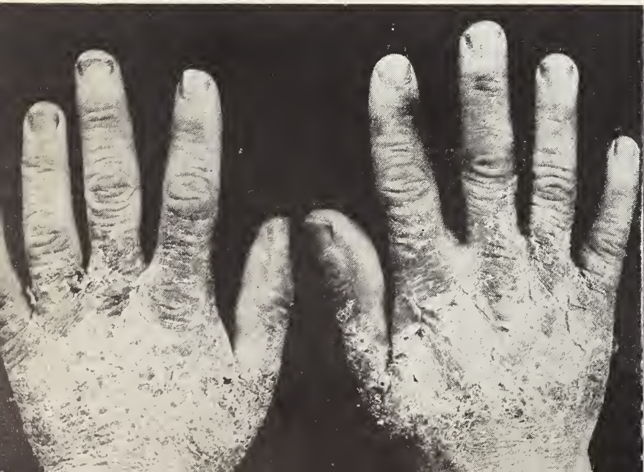
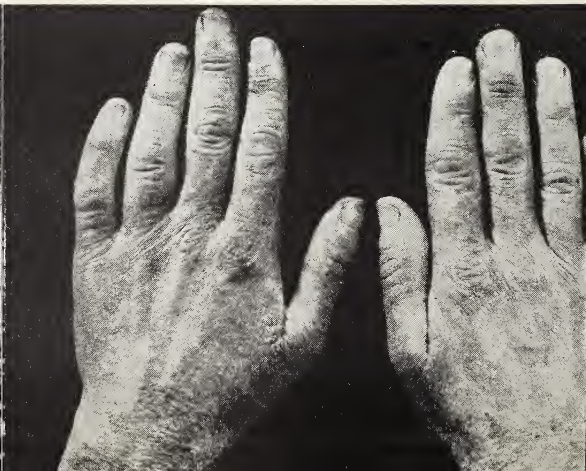
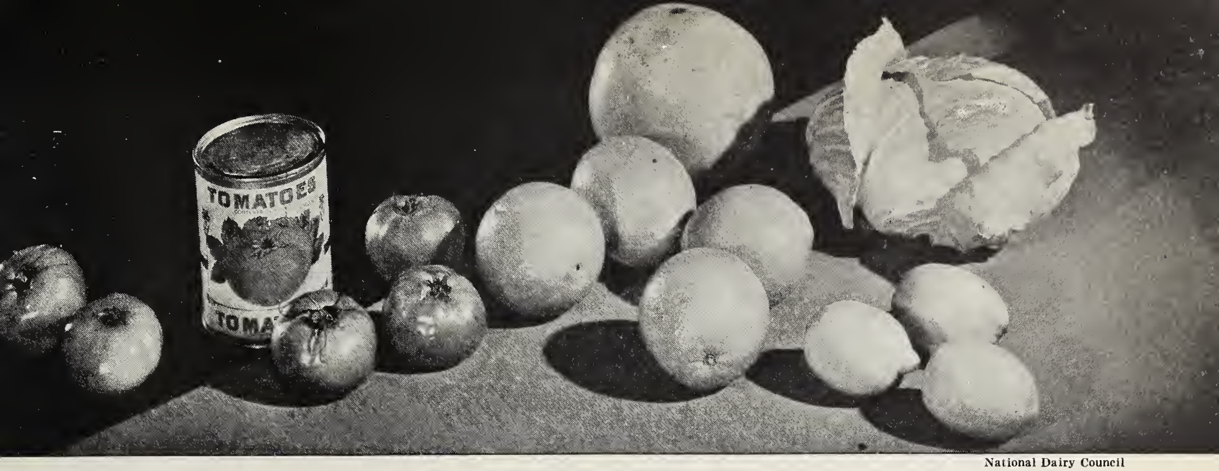


A marked improvement is often soon noted in the pellagra-afflicted patient treated with nicotinic acid





National Dairy Council

Foods rich in vitamin C

diet deficient in this vitamin, they contracted a skin disease about the nose and paws. This disease completely disappeared when small doses of vitamin B_6 were administered daily.

Pantothenic Acid. The empirical formula of the calcium salt of this vitamin factor is $(C_8H_{14}O_5N)_2Ca$. The function of pantothenic acid has not been definitely determined, although it is thought to have some function in the maintenance of healthy skin.

Nicotinic acid. This factor of the vitamin B complex is known as the antipellagra factor, since its presence in the diet in sufficient amounts will prevent the disease pellagra. This disease is recognized usually by a red skin rash which turns black on exposure to sunlight. Pellagra is not uncommon in the southern part of the United States, where the diet of certain classes of people is deficient in nicotinic acid. Investigations in recent years have proved that this disease can be completely eliminated if the proper foods are eaten.

Nicotinic acid is also known to have some control over the functioning of the nervous system, the skin, and the gastrointestinal tract.

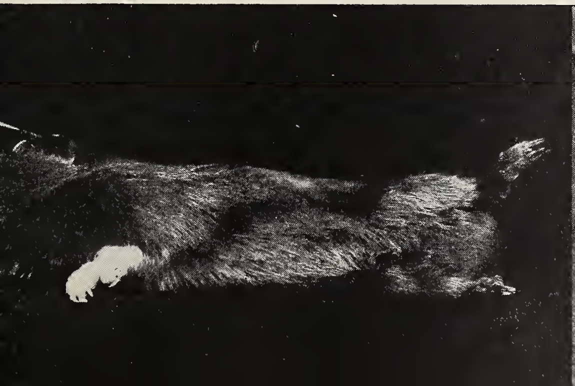
The principal sources of this vitamin are liver, egg yolk, milk, lean meat, yeast, and raw vegetables. Many processed foods, such as flour, are now being enriched with several of the vitamin B complex factors.

Vitamin C (soluble in water). This has been made in the laboratory and has the formula $C_6H_8O_6$. Chemically it is an acid. From the formula it is evident that vitamin C is simple in structure compared with vitamins A and B.

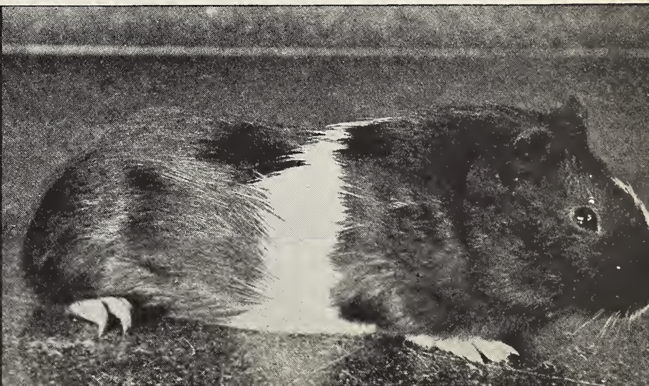
Vitamin C is readily decomposed by oxidation. Although ordinary cooking probably does not completely destroy it, care should be taken to heat foods in closed vessels so that the oxidation of this vitamin will be retarded.

The guinea pig is very susceptible to a deficiency of vitamin C and rapidly develops scurvy, one evidence of which is seen in the enlargement of the bones at the joints. If completely deprived of vitamin C, most guinea pigs die in about three weeks. Untreated scurvy in man is also fatal

E. R. Squibb and Sons



A guinea pig cured of scurvy by the administration of ascorbic acid (vitamin C)



National Dairy Council

These foods are rich in vitamin D

A continued deficiency of vitamin C in the diet causes the disease scurvy. This disease may result in hemorrhages in the skin and gums, and often the teeth become loosened. Since pasteurization of milk has become common, scurvy among children has increased. This is due to the destruction of vitamin C in the pasteurization process. Therefore, care should be exercised in supplying the child with other foods rich in vitamin C.

Vitamin C is sometimes called the antiscorbutic (scurvy-resisting) vitamin. The best sources of this vitamin are citrus fruits, strawberries, tomatoes, tomato juice, and raw cabbage.

Vitamin D (soluble in fats). There is probably no vitamin so highly advertised as vitamin D. Its value to the body is widely known; but it is relatively scarce, and many children and adults suffer from a lack of this important vitamin.

Vitamin D is crystalline in structure, and its formula is not definitely known. However, the substance from which it is produced is known to be *ergosterol*, a fatty substance found in the tissues of plants and animals. Ergosterol is known as the precursor of vitamin D. To manufacture vitamin D from ergosterol the body must have the ultraviolet rays of sunlight. Whenever ultraviolet rays react with ergosterol, whether it be in plants or animals or in foods, vitamin D is produced. For this reason, a person who is out in the sunlight a great deal probably receives sufficient vitamin D.

You have probably seen such foods as milk, bread, and meat advertised as containing vitamin D. Either such foods have had this vitamin added directly, or they have been subjected to ultraviolet rays, which change the ergosterol in them to vitamin D. Generally these ultraviolet rays are produced by special electric lights. The process of exposing a food containing ergosterol to ultraviolet rays is called irradiation. Irradiated ergosterol, which contains pure vitamin D, is now sold under the name of calciferol. Irradiated ergosterol may also be called synthetic vitamin D.

Vitamin D face creams, lipsticks, hand lotions, soaps, etc. are now being sold. Scientific experiments indicate that such a source of this vitamin is valueless. Vitamin D cannot be sufficientlv absorbed through the skin to be of any benefit.

Vitamin D has a sort of foreman's job in the body

E. R. Squibb and Sons

The function of vitamin D is that of controlling the metabolism of calcium and phosphorus in the body. The diet does not always supply to the body the correct proportions of these two elements, but if sufficient vitamin D is present the proper deposition of calcium and phosphorus will be assured. To assure the correct assimilation of calcium and phosphorus in the bones and teeth, it is essential that the diet be rich in these elements and that the body receive plenty of sunlight.

A deficiency of this vitamin limits the deposition of calcium and phosphorus, causing poorly formed and decayed teeth, as well as a softness of the bones. Continued deficiency results in the disease rickets. For this reason, it is known as the antirachitic vitamin.

Rickets generally occurs during the first few years of a child's life. It is recognized by bowlegs, knock-knees, and sometimes curvature of the spine and a narrow pelvic bone. Rickets in adults is characterized by softening of the bones, hysteria, and rheumatism.

If the body receives an excess of vitamin D, a toxic, or poisonous, condition may result. Overdoses may cause an excess of calcium and phosphorus in the blood, which will be deposited in various parts of the body in excess. The deposition frequently takes place at the ends of the bones, causing an enlargement, or in the soft tissue, such as the kidneys. Because there are so many commercially prepared vitamin D concentrates now being widely advertised, there is danger that the uninformed person may be harmed by their indiscriminate use. These preparations are being sold in capsules and bottles as halibut-liver and cod-liver oils which have been fortified with excessive amounts of vitamin D and other vitamins. Every precaution should be exercised in using such preparations. They should be used only on the advice of your family doctor.

Among the best sources of vitamin D are egg yolk, cheese, butter, and liver. This vitamin in the diet may be supplemented by the use of cod-liver oil, halibut-liver oil, and irradiated foods, such as irradiated milk and bread. Moreover, you should be certain that you are receiving plenty of calcium and phosphorus in your diet, and, above all, you should get plenty of sunlight.

Vitamin E (soluble in fats). This vitamin, which is sometimes called the antisterility vitamin, is thought to have some effect upon reproduction. It has been found to be essential to successful reproduction in rats, although its effect on human beings is not fully understood.

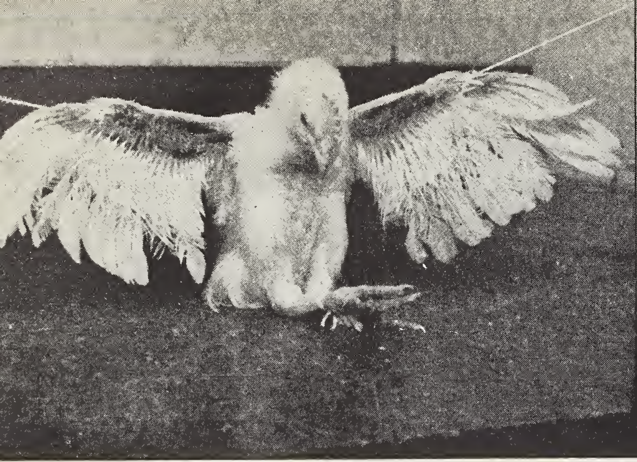
Vitamin E has been obtained in pure crystalline form and is soluble in fats. It is not affected by heat, can be stored in the body, and is so widely distributed that there is very little danger of a deficiency of it in the diet. The most important sources of this vitamin are wheat germ, green, leafy vegetables, whole-grain products, meat, and egg yolk.

Some recently discovered vitamins. A great deal of vitamin research and experimentation is now being carried on in the United States. This has resulted in the discovery of a number of new vitamin factors, about some of which little is known. Undoubtedly more vitamins will be discovered as time goes on.

Vitamin K, known as the antihemorrhagic factor, is necessary in the body for the blood to clot. A deficiency of this vitamin is known to cause hemorrhages. Under certain conditions vitamin K is used to stop hemorrhages and to improve the clotting quality of the blood following an operation. It has been used to save the lives of babies who were in danger of bleeding to death during their first week of life. Vitamin K has also made possible operations on people with jaundice, who often bleed to death following an operation. Experiments are now being

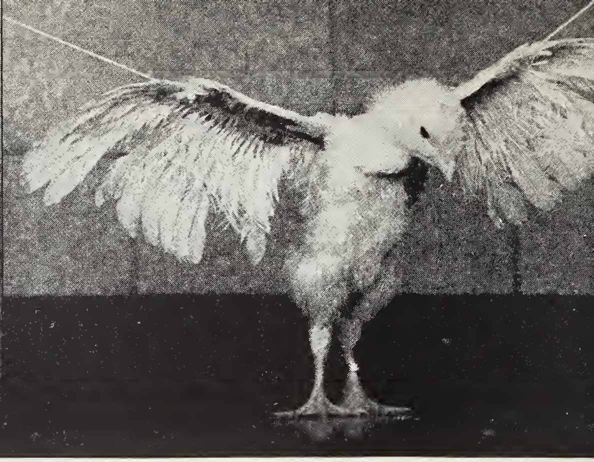
Given an adequate dose of vitamin E, animals previously sterile because of a deficiency of this factor will produce and rear a litter of normal young. Vitamin E is sometimes called the antisterility factor

E. R. Squibb and Sons



E. R. Squibb and Sons

Characteristic hemorrhage resulting from a deficiency of vitamin K. This vitamin is necessary for blood to clot



The rapidity with which the clotting time of the blood is restored to normal after an administration of vitamin K is striking

carried on to determine the role of vitamin K in the fight against cancer.

Vitamin B_p has some relationship to the development and shape of the bones. Another B-complex vitamin is now being used experimentally to prevent hair from turning gray.

EXERCISES

1. How are amino acids used by the body tissue?
2. What happens to the amino acids which are not used to build tissue?
3. What determines the protein requirement of the body?
4. What is meant by an incomplete protein?
5. How much protein does the body require daily?
6. Why does not the body store proteins?
7. Is there likely to be a deficiency of protein in the average diet?
8. What dangers may result from an excess or a deficiency of protein in the diet?
9. Where do the carbohydrates go after passing through the intestinal wall?
10. How is glucose used in the body? Write an equation for the reaction.
11. What happens to any excess glucose which is not immediately used in the body?
12. How does the digested fat get into the blood stream?
13. What use is made of fat in the body?
14. What uses are made of minerals in the body?
15. How do mineral salts build and maintain tissue?
16. Why must the body be supplied with some minerals every day?
17. What body processes do mineral salts regulate? How?
18. Is there any danger of disturbing the acid-base balance of the body? Why or why not?
19. Which common foods are acid-forming? Which are base-forming?
20. What uses are made of calcium and phosphorus in the body?
21. What happens if the body does not get the required amount of calcium and phosphorus?
22. What function do iron and copper have in the body?
23. What causes anemia?
24. What foods are rich in calcium? phosphorus? iron and copper?
25. What use is made of iodine in the body?
26. What causes goiter? How may it be prevented?
27. What are the functions of vitamins?
28. How is vitamin A obtained by the body?
29. What function does vitamin A have?
30. What foods are rich in vitamin A?
31. What happens if the body does not secure the required amount of vitamin A?
32. What is the function of vitamin B?
33. What may result if the body does not get a sufficient amount of vitamin B?
34. What foods are rich in vitamin B?
35. What effect does a deficiency of vitamin C have upon the body?
36. What foods are rich in vitamin C?
37. How is vitamin D manufactured in the body?
38. What is the function of vitamin D?
39. What is the best source of vitamin D? What are other sources?

40. What happens if the body does not get the required amount of vitamin D?

41. Are irradiated foods and foods with vitamin D added good sources of this vitamin for the body? What about vitamin D cosmetics?

42. What is the function of vitamin E?

43. What may result from a deficiency of vitamin G, or B_2?

44. What foods are rich sources of vitamin G, or B_2?

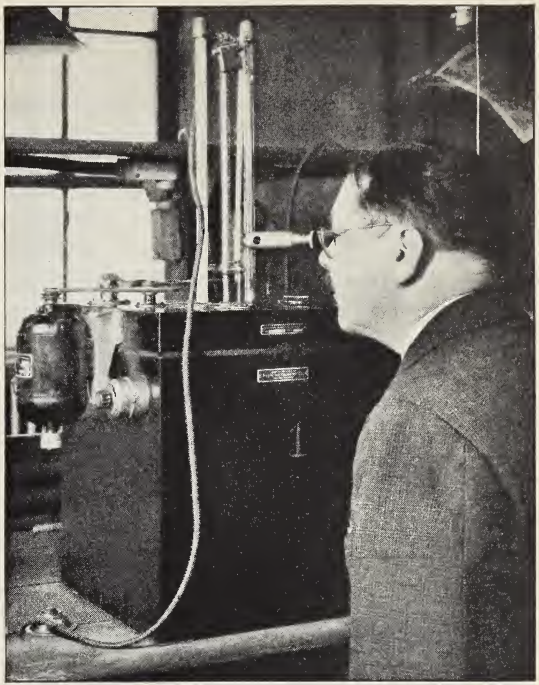
45. Name and give the uses of some newly discovered vitamins.

Problem 6. What is the energy requirement of the body?

Three purposes of body energy. In the discussion of the three nutrients proteins, carbohydrates, and fats, we frequently referred to the fact that they supply energy to the body. It is now our purpose to discover what use the body makes of this energy.

The body needs this energy for three distinct purposes: (1) to maintain a normal temperature, (2) to build tissue, especially during childhood and pregnancy, and to keep the tissue in constant repair, and (3) to carry on the various kinds of work which the body must do. For a more thorough understanding let us discuss each of these needs.

1. Except for unusual cases and circumstances, the



Ewing Galloway

By means of this device, the bomb calorimeter, chemists determine the energy value (in calories) of foods. Can you explain how this device works?

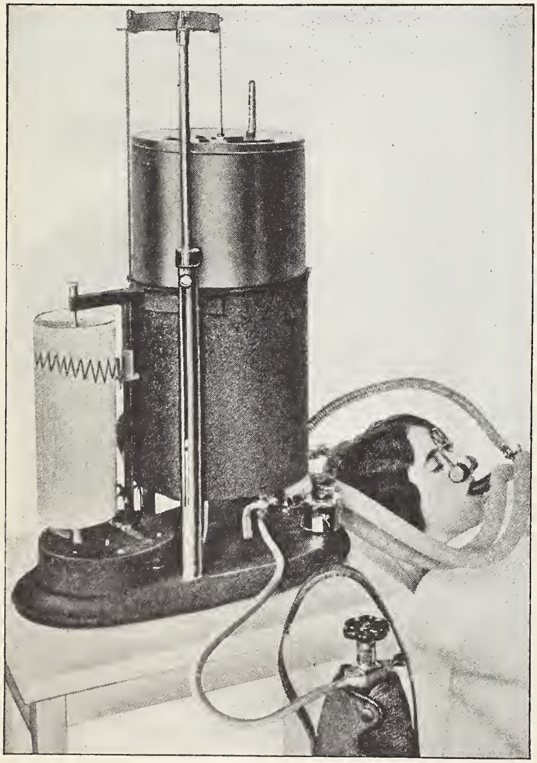
Energy-producing foods

National Dairy Council

need of heat energy for maintaining normal body temperature is of minor importance. Such conditions as lack of adequate clothing, unusually cold, dry climate, and exceptionally large body surface would demand an appreciable amount of heat from the oxidation of food. However, under normal conditions, it may be said that but little food is necessary to maintain the body at its normal temperature, 98.6° F (37° C).

2. At least one eighth of the food intake of a rapidly growing child is used in the building of new tissue. In like manner, the necessity for extra energy during pregnancy should be recognized. Illness is generally accompanied by the destruction of tissue, and during convalescence an added amount of energy must be available to rebuild and repair this tissue. The body requires energy, as well as protein, in the building of new tissue. The energy is necessary to change the amino acids to protein.

This apparatus is used for determining basal metabolism[1]



3. From the point of view of the whole span of life, the greatest amount of energy is needed for the work the body must do. Let us consider this work from two distinct angles: (*a*) within the body and (*b*) outside the body.

a. In discussing the energy needed within the body, let us consider the case when the body is at rest. Think of all the vital processes that must continue incessantly even when one is asleep. The work of the liver and kidneys, the beat of the heart, the normal respiratory movements, the work of the glands, and many other functions must continue until death. These functions certainly demand a continuous supply of energy. A still greater demand comes from the fact that oxidation in the tissues is constant, even when the body is at rest. This reaction is essential in keeping the tissues living and ready for action. It is estimated that, in a normal adult, three fourths of the internal energy requirement is used in oxidation.

The heat produced in the body while at rest in maintaining the functions mentioned above may be determined through the use of a respiratory calorimeter. This device measures the amount of oxygen consumed in the oxidation of food and the amount of carbon dioxide liberated after oxidation takes place. From these determinations the number of calories of heat produced per minute can be calculated. The heat output in calories per minute of the body at rest and without food for from twelve to eighteen hours previous to the calculation is called *basal metabolism.*

b. Consider for a moment the muscular activity that the body undergoes in a normal day. Also, consider the fact that any movement of the body, though it be merely the wiggle of a finger, demands energy above that used for maintaining the normal internal functions. When one realizes the great amount of muscular activity that even a person leading a quiet life experiences, it is evident that a great amount of the heat energy of oxidation must be converted into energy to produce muscular work.

It is probably clear to you from this discussion that it would be impossible to determine definitely an energy requirement that would apply to all persons. The man who rides to work in an auto-

[1] Reproduced from Andress, Aldinger, and Goldberger's *Health Essentials*, Ginn and Company.

mobile, sits in his office all day, and takes no regular exercise would naturally demand much less food energy for muscular activity than a woodchopper would or any person engaged in strenuous physical activities.

How is the fuel value of foods measured? The method most used to determine the fuel value of foods is that of the bomb calorimeter. In a heavy steel bomb, which is immersed in water, a weighed sample of food is placed. The bomb is then charged with oxygen under pressure, and the sample is ignited with an electric fuse which produces complete combustion. The total heat produced is then determined.

To determine the heat-producing, or energy-producing, value of food, a unit known as the calorie (abbreviated cal) is used. A food calorie is the amount of heat necessary to raise a kilogram (abbreviated kg) of water 1° C, or 4 pounds of water 1° F. By the use of the calorimeter it is possible to determine the energy value in calories of all kinds of food.

What determines the amount of energy that the body requires? You are aware of the fact that no two persons are exactly alike and that very few people work and live under the same conditions. For these reasons the amount of food a person eats to satisfy his energy requirement varies with each individual. A person large in stature requires more energy than one who is small in size. You probably know some people who live the same kind of life, and yet require different amounts of food for energy. This is because of a variation in their ability to digest and assimilate food. Another factor which determines the energy requirement is the amount of excess fat. Moreover, a person who is engaged in strenuous physical exercise or muscular work will need more energy-giving food than one who leads an inactive life. For a growing person the amount of energy required depends upon the rapidity of growth. Finally, the climate that a person lives in and the type of clothing and shelter that he uses will influence the amount of energy-producing food which he must eat.

How many calories of energy does the body require? In our attempt to arrive at some method of calculating the energy requirement of the body, we must constantly recall that no hard-and-fast rule can be used. The conditions which determine the energy requirements of different individuals are never the same, and hence results secured by the method of calculation given here will be only approximately correct. Accurate information can be obtained through a series of tests which dietetic physicians are capable of administering. Scientists

The amount of each food shown here will produce 100 calories of heat when burned in the body

are making every effort to determine the exact energy requirement of the body.

Under normal conditions, it is estimated that the average adult requires for basal metabolism 1 calorie per hour for each kilogram, or 2.2 pounds, of weight. In the case of a person living a quiet life, such as an office worker who takes but little exercise, an additional 35 per cent of the basal metabolism must be added for muscular energy. The fact that not all the food eaten is digested necessitates another addition of about 5 per cent. The requirement for muscular activity increases according to the exercise involved in an occupation and the daily habits of life. Thus a farm laborer might require as much as 100 per cent more calories than are required for basal metabolism, while an active lumberman might require an additional 200 per cent.

Calculate the energy requirement for an adult weighing 145 pounds and living a rather quiet life:

For basal metabolism . . . . $\frac{145}{2.2} = 65.9$ calories per hour
For muscular activity . 65.9 × .35 (35 per cent) = 23.1 calories per hour
For food not digested . 65.9 × .05 (5 per cent) = $\underline{3.3}$ calories per hour
Total = 92.3 calories per hour
92.3 × 24 hours = 2215.2 calories per day

A general estimate of the calorie requirement is as follows:

For a person living quietly	2000 to 2500 calories
For a person engaged in moderate activity . . .	2500 to 3500 calories
For a person more active than the average . . .	3500 to 4500 calories

In the case of infants and children, it must be remembered that part of the energy requirement must be provided for growth. For a child in its first year, it is estimated that the total requirement will run about 4½ calories per kilogram (2.2 pounds) of weight per hour. As the child increases in age, the requirement is gradually diminished. At the ages of 11 to 14, provided growth is continuing, the total requirement will be about 2 calories per kilogram of weight per hour. For a high-school student (ages 14 to 17) who has not completed his growth, the total requirement will average about 1.75 calories per kilogram of weight per hour. When growth is abnormal, these estimates will not apply.

What is the energy value of various foods? The energy value of foods is based upon the percentages of carbohydrates, fats, and proteins in each particular food. By referring to the table on page 167, it is possible to obtain the approximate energy value in calories of an average table serving of various commonly used foods. A more nearly complete list of foods, with their energy values, may be obtained from several well-known reference books which are mentioned in the bibliography on page 175.

EXERCISES

1. Why does the body need energy?
2. How does energy from food help to maintain normal body temperature?
3. How does the energy from food aid in building new tissue and in keeping the tissue in repair?
4. What work must the body do?
5. How does the energy from food help the body to do its work?
6. What is meant by basal metabolism?
7. How is the energy value of food measured? Describe fully.
8. What factors determine the amount of energy that the body requires?
9. Describe fully how to calculate the number of calories of energy that the body requires. Use your own body as an example.
10. How may one discover the energy value of various kinds of food?

Problem 7. What are the best sources of the food nutrients?

Select foods carefully. It is characteristic of the American people to eat the kinds of foods they enjoy eating without regard for the food requirements of the body. Your present knowledge of the purposes, properties, characteristics, digestion, and use of food and your knowledge of the body requirements should make you more cautious and exacting in the selection of food. If you are to be intelligent in the selection of food for your daily diet, you need to know those foods which are capable of supplying the body with the necessary nutrients. It will be well, at this point, to gain a general knowledge of those foods which are richest in each of the nutrients.

Protein is the basic nutrient for building and rebuilding body tissue. Foods containing from 10 per cent to 30 per cent protein are eggs, meat, cheese, and nuts; from 3 per cent to 10 per cent, milk, bread, and cooked cereals. Growing children may be assured of a sufficient amount of protein by including

Nutritional Value of Food (Approximate)

Food	Size of Portion (Average Serving)	Weight (Grams[1])	Protein (Per Cent)	Carbohydrates (Per Cent)	Fats (Per Cent)	Iron (Grams)	Calcium (Grams)	Phosphorus (Grams)	Energy (Calories)
Apple	1 medium	88	0.4	14.2	0.5	.000316	.0062	.0105	55
Asparagus	8 stalks, 6″ × ½″	138	2.1	2.2	3.3	.00139	.034	.0543	30
Banana	1 medium	100	1.3	22	0.6	.00064	.0091	.0313	100
Beans, String	⅓ cupful	44	2.3	7.4	0.3	.00048	.0202	.0228	18
Dried	⅓ cupful	63	22.5	59.5	1.8	.00497	.1008	.297	217
Lima	⅓ cupful	55	18.1	65.9	1.5	.00131	.0187	.0724	67
Beef, Roast, lean	2 slices, 3″ × 3″ × ¼″	150	21	----	12.2	.00519	.0183	.3396	160
Steak, lean	1 portion, 3″ × 3″ × ½″	150	21.3	----	10.4	.00594	.0209	.3381	240
Beets	⅓ cupful, diced	51	2.3	7.4	0.1	.00043	.0145	.0200	31
Bread, Whole wheat	Bakery slice	27	9.7	49.7	0.9	.00043	.0134	.0472	64
White	Bakery slice	27	9.2	53.1	1.3	.000243	.00729	.0251	68
Butter	1 pat, ¼″ thick	7	1.0	----	85	.000013	.0011	.0011	48
Buttermilk	1 glass (8 oz.)	250	3.0	4.8	0.5	.00062	.2605	.2408	89
Cabbage	⅓ cupful	61	1.6	5.6	0.3	.00026	.0211	.0174	15
Carrots	⅓ cupful, diced	63	1.1	9.3	0.4	.00040	.0351	.0288	24
Cauliflower	⅓ cupful	73	1.7	4.5	0.45	.00068	.0894	.0443	18
Celery	2 stalks, 8″	42	1.1	3.3	0.1	.00025	.0312	.0149	8
Cheese, American	1 slice, 3″ × 2″ × ¼″	29	29.1	0.2	37.5	.00038	.2791	.2047	128
Cottage	⅓ cupful	75	20.9	4.3	1	----	----	----	----
Swiss	1 slice, 3″ × 2″ × ¼″	23	27.6	1.3	34.9	.000310	.2231	.1637	102
Cherries	⅓ cupful	58	1.1	16.7	0.1	.00023	.0108	.0177	45
Chicken	1 leg or equivalent	148	21.5	----	2.5	.00483	.0185	.3473	159
Corn	⅓ cupful	57	2.9	19.2	1.2	.000457	.0034	.0590	58
Eggs	1 medium	60	13.4	----	10.5	.0018	.0402	.108	89
Fish, baked	1 slice, 4″ × 3″ × ½″	160	18.7	----	2.1	.00164	.0325	.3433	124
Gelatin	Dessert serving	110	91.4	----	0.1	----	----	----	----
Grapefruit	½, 5″ diameter	188	0.6	14.4	1.2	.000517	.039	.0354	99
Ham, lean, smoked	1 slice, 3″ × 4½″ × ½″	162	19.8	----	20.8	.00130	.0053	.0884	111
Lamb									
Chops	2 medium, ½″	160	20.1	----	23.2	.004732	.0189	.3402	166
Roast, lean	2 slices, 3″ × 3″ × ¼″	160	20.1	----	23.2	.004732	.0184	.3402	166
Lemon juice	2 tablespoons	30	----	9.8	----	.000150	.0072	.0030	12
Lettuce	½ small head	138	1.2	2.9	0.3	.00096	.059	.0586	23
Liver, beef	1 slice, 4″ × 4½″ × ¼″	100	20.4	1.7	4.5	.0082	.0181	.220	154
Milk, whole	1 cup (8 oz.)	246	3.3	5.0	4	.000587	.2931	.2271	158
Molasses, cane	1 tablespoon	20	2.4	69.3	----	.001496	.0432	.0090	56
Oatmeal	⅓ cupful	16	16.1	67.5	7.2	.00172	.032	.1768	183
Onion	1, 2½″ diameter	120	1.6	9.9	0.3	.000569	.0405	.0534	58
Orange	1, 3″ diameter	130	0.8	11.6	0.2	.00067	.0585	.0276	68
Oysters	6 medium	120	6.2	3.7	1.2	.0054	.0625	.186	60
Peaches	1, 2½″ diameter	172	0.7	9.4	0.1	.00057	.0280	.0418	70
Pears	1 medium	150	0.6	14.1	0.5	.0005	.0237	.0407	98
Peas	⅓ cupful	60	3.6	9.8	0.2	.00124	.1068	.0762	61
Potato	1, 3″ long × 3″ diameter	250	2.2	18.4	0.1	.00227	.035	.145	208
Prunes	3 large	30	2.1	73.3	----	.00085	.0161	.0314	90
Raspberries	⅓ cupful	47	1.1	12.6	----	.00041	.0228	.0232	26
Spinach	⅓ cupful	68	2.1	3.2	0.3	.00171	.0450	.0453	15
Strawberries	½ cupful	90	1	7.4	0.6	.000612	.0368	.0252	35
Tomato	1, 2½″ diameter	135	0.9	3.9	0.4	.000613	.0151	.0360	27
Turnip	1, 2½″ diameter	102	1.3	8.1	0.2	.00052	.0638	.0461	30
Watermelon	1 slice, 9″ × 1″	550	0.4	6.7	0.2	.00156	.0608	.0165	165
Whole-wheat cereal	½ cupful	15	11.1	75.4	1.5	.0012	.0102	.0971	63

[1] 28.35 grams = 1 ounce.

in the daily diet at least a quart of milk, an egg, and a liberal amount of cereal foods.

Foods rich in carbohydrates are those that contain sugars and starches. Foods rich in fats are equally well known—for example, butter, lard, fatty meats, cream, vegetable oils and fats, egg yolk, and cheese. Except when a person is on a restricted diet, there is but little danger of his suffering from a deficiency of these energy-giving foods.

Sodium chloride (common table salt) is a necessary mineral which is found in the food we eat. Therefore it is not necessary to add much of this mineral to our food. Too much salt produces an excessive strain on the kidneys, since any excess must be eliminated. It is safe for each normal person to consume about 10 grams per day. Moderate seasoning of food in the kitchen will supply this amount.

To ensure an adequate amount of minerals in the daily diet, it is necessary to include such foods as fruit, vegetables (especially the green, leafy ones), and milk. Whole-grain breads and cereals are also valuable in providing the body with minerals. Three or four servings a day of both vegetables and fruits and a pint of milk are generally sufficient to supply the body requirement of minerals.

The best sources of each vitamin have been given in the discussion of Problem 4. It is well to keep in mind that adequate amounts of such foods as milk, butter, eggs, fresh vegetables (especially the raw and green, leafy ones), whole-grain products, and fruits (especially citrus fruits) will probably supply the vitamin requirement of the body. Any additional vitamins which the body may need should be prescribed by your physician.

EXERCISES

1. Are people sufficiently careful about the selection of food? Discuss fully.

2. What are the best sources of proteins? carbohydrates? minerals? vitamins?

Salt is a necessary part of the diet of all living creatures. Why?

Ewing Galloway

Problem 8. What dangers may result from the improper use of food?

Proper food essential to a healthy body. By this time you are aware of the fact that food is probably the most important factor in the growth of a strong, healthy body. From the minute the body begins to grow until it reaches its maturity, food is being used to build muscle, bones, teeth, hair—in fact, every tissue in the body. Should the body be denied the proper kind and amount of food, it is reasonable to believe that the growth of body tissues could not be carried on to perfection. The elements which compose the body must be supplied to it by the food we eat; otherwise deformity or disease will result.

The importance of diet during pregnancy and during the growth of a child cannot be overstressed. Deformities that result from the lack of nutrients during these periods are many and varied. Bowlegs, knock-knees, curvature of the spine, poorly formed teeth, and many other conditions have been traced to improper diets. Many diseases can be labeled as strictly dietary in nature. Others are at least partially caused by faulty diet. Such diseases as scurvy, rickets, pellagra, and beriberi could be completely eliminated by balanced diets.

Moreover, the improper use of food may also aggravate certain diseased conditions of the body. Thus diabetes will become more severe if too much starch and sugar are eaten; hay fever is intensified by certain foods; goiter may result from a diet which does not contain food rich in iodine; chronic constipation is encouraged when the diet is deficient in roughage and vitamin B. Finally, many unhealthful conditions of the body may result from the body's being allergic to certain foods.

EXERCISES

1. Make a list of diseases and other conditions of the body which may result from insufficient amounts and improper use of food.
2. What periods and conditions of life necessitate great care in the selection of the food we eat?

Problem 9. Is it wise to "diet"?

Be wary of food fads. You need only glance through newspapers and magazines or listen to radio patter to realize that Americans have been and are being "sold" on the idea that it is fashionable to have a "slim and graceful figure." Many people regard this body characteristic of slimness as so attractive that they are willing to go to any extreme of dieting when excess weight begins to appear. The unfortunate part of this is that dieting is often carried to a point where great harm is done to the body.

If one were to make a scientific investigation, he would find that those who advocate adherence to diet fads have utterly disregarded two important factors which should always be considered in relation to reducing. The first is that overweight is not always caused by overeating, and the second is that the body requires a certain amount of each food nutrient to maintain a normal, healthy condition.

It is well known in medical circles that at least some cases of overweight are caused by the improper functioning of certain glands. This condition will be discussed in some detail in the unit which follows. It is also known that many of the starvation diets recommended for persons who are overweight because of glandular disturbances will result in inestimable harm to the body.

Many of the so-called "scientific" diets are based upon eliminating those nutrients which will build tissue. These nutrients, as you have learned, are fats, proteins, and carbohydrates. When these nutrients are reduced in the diet below body requirements, the body begins burning stored fat so that it can supply the necessary energy to the body. In addition, these diets make no provision for replacement of muscle tissues which are destroyed in the normal functioning of the body. Such a destruction of tissue, which has been built through a slow, gradual process, can only be safely accomplished over a long period of time and through an intimate knowledge of the requirements of each individual who is attempting to reduce.

The most damaging part of many diet fads is that they bring about weight reduction in too short a time. In such a practice, tissue is destroyed so rapidly that the body cannot adjust itself to the changing conditions. In many cases, this may cause the regularity of bodily functioning to be disturbed and may result in many ill effects. Such harm done to the body may never be righted in a lifetime.

"This is the only safe way to learn how to reduce"
PATENT FAT REDUCING FOODS AND DIET
GLANDS
PAUS

The sensible person seeks the doctor's advice on diet

It is of the utmost importance that any abnormal increase in weight be closely watched. At the same time, it is well to keep in mind that reasonable variations from the normal weight need not cause alarm. We are all individuals, each with a different body structure, which makes what we call normal weight only of very general value. When excessive weight occurs, it is easily recognized. If such a condition does exist, the process of removing the excess weight is far too critical to be dealt with by anyone except one who has an extensive knowledge of the human mechanism, preferably a dietetic physician.

An underweight condition of the body is just as serious as overweight. A person may be underweight because of disease, improper functioning of the body, lack of adequate food, or poor habits of eating. If the body is appreciably below normal weight, it becomes more susceptible to disease, tires easily, and produces a nervous condition.

In the majority of cases, a person can gain weight by eating more food. A careful inspection of the diets of many persons who are underweight will show that they are failing to get the right amount of calories to maintain normal weight. Where underweight is caused by disease or functional disturbances, it is essential that an examination be made by a skilled physician.

EXERCISES

1. Why do people "diet"?
2. Are the so-called diet fads safe? Why or why not?
3. What causes some people to be overweight?
4. How should one go about reducing?
5. How can a person increase his weight?

Problem 10. How do emotional disturbances affect digestion?

Emotional disturbances retard digestion. Anger, pain, and fear have a bad effect upon the digestion of food. Emotions are definitely allied with the nervous system, and any one of the three mentioned will cause irregular action of the peristaltic motion of the stomach and intestines and slow down the secretion of fluids from the digestive glands.

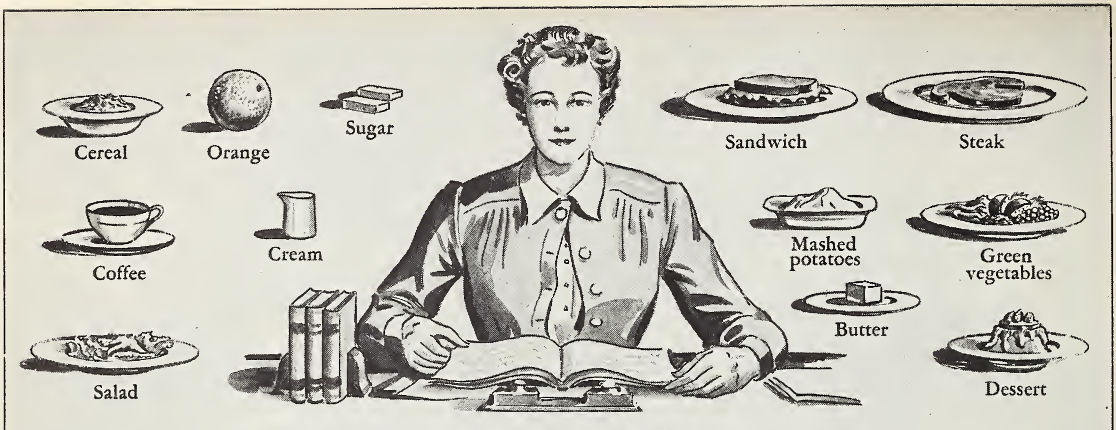
There are many conditions which will definitely arouse the emotions and thereby cause digestion to be upset and retarded. Continuous worry causes many people to lose a desire for food; sudden fright may result in a complete loss of appetite; the shock of the news of a death, a rebuke just before mealtime, can completely eliminate the feeling of hunger.

It is important that, as far as possible, living be so organized that the emotions are not excited before or during mealtime. Many of the practices which excite the emotions can and should be done away

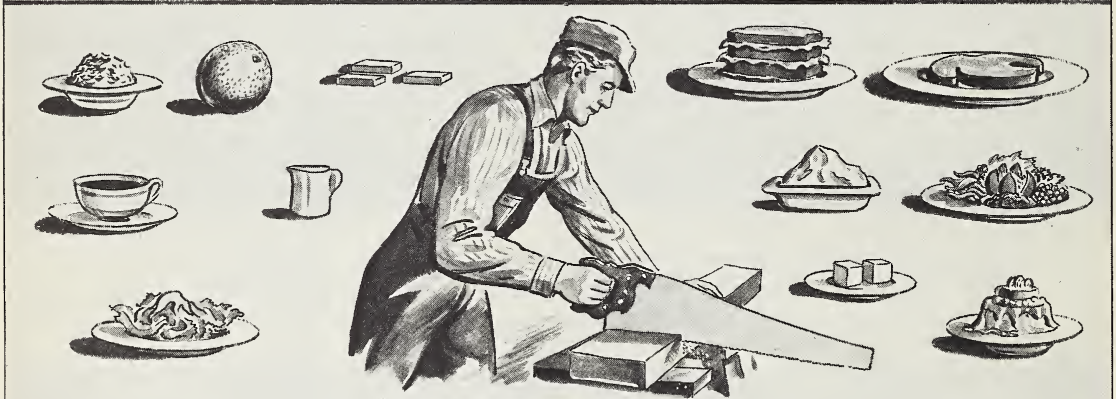
Ewing Galloway

The family meal should be a happy occasion. Food eaten by a person who is emotionally upset is not digested well. Food attractively served to people in good spirits increases appetite and aids digestion

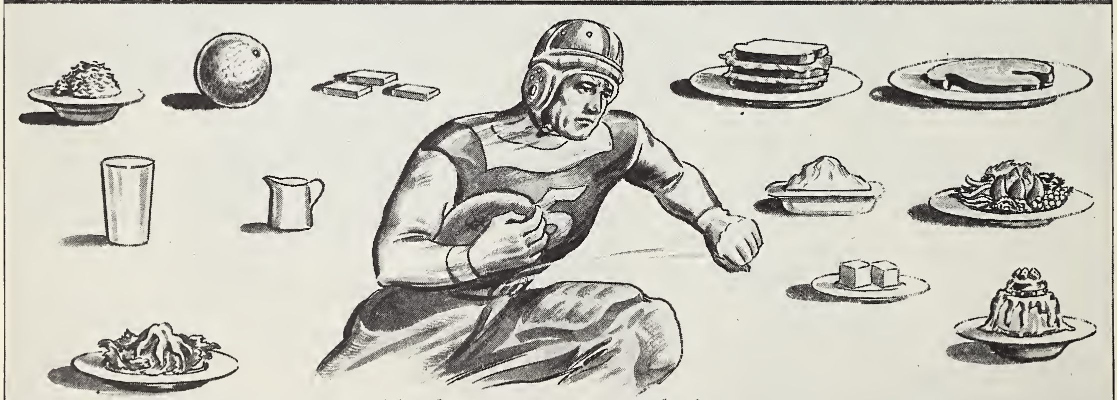
Ewing Galloway



Total, 2000 to 2500 calories



Total, 3000 to 3500 calories



Total, 3500 to 4000 calories

Why does each of these persons require a different amount of energy-producing foods?

with. For instance, children should not be scolded and punished at mealtime; unpleasant experiences and happenings should not be discussed; the arrangement of the table and the serving of the meal should be such as to suit the most particular member of the family. In fact, mealtime should be a smoothly organized period in which all activities should tend to promote the fullest possible enjoyment of the food.

EXERCISES

1. What is meant by emotional disturbances?

2. How do emotional disturbances affect digestion?

3. How may emotional disturbances be avoided?

PROBLEMS FOR FURTHER STUDY

1. Using the information which is given on pages 165–166, calculate the approximate energy requirement of your body. If you have reached your maximum growth, you should use the method in which you will have to estimate the allowance for muscular activity. If you are still growing, the best estimate will probably be obtained from the total energy requirement of 1.75 calories per kilogram per hour.

2. *a.* Make a list of all the foods that you have eaten during a particular day.

b. Using the table on page 167, estimate the calorie value of each food. (If you do not find a certain food listed in this table, it will be necessary for you to refer to tables recommended in the bibliography.)

c. Find the total calorie value of the food eaten.

d. Compare this total calorie value with your requirement as calculated in Problem 1.

e. From these calculations, it will be interesting to consider the following:

1. If you are underweight, is it due to a deficiency in calorie intake?

2. If you are overweight, is it probably due to too great a calorie intake?

3. If your weight is normal, do you find that your calorie intake is nearly the same as your requirement?

3. Of what value are foods such as bread and milk which are advertised as containing vitamin D?

4. Is it safe to confine the diet to vegetables?

5. Work out a weekly diet which will supply all the nutrient requirements for a high-school junior or senior.

6. Select an advertised reducing diet and compare the food nutrients which it supplies to the body with the actual body requirements.

7. Make a collection of food advertisements which make special claims regarding the value of certain foods to the body. Analyze these claims in the light of authoritative evidence and report your findings and conclusions to the class.

Good health depends on good food. How do you know that this is a well-balanced meal?[1]

8. Are fried foods unwholesome?

9. Make a study of the allergies caused by foods.

10. Is sauerkraut juice healthful? Why or why not?

11. What is viosterol? Should it be used without a doctor's advice?

12. What is homogenized milk? What is its value compared with ordinary milk?

13. Write to the Bureau of Home Economics, Washington, D.C., to obtain bulletins on balanced diets for those in the low-income groups and discuss them with your class.

UNIT EXERCISES

A. Some of the statements which follow are true, and some of them are false. On a separate sheet of paper write the word *true* for those which are true and the word *false* for those which are false. Write nothing for those about which you are doubtful. Rewrite the false statements so that they are true.

---

[1] Reproduced from Powers, Neuner, Bruner, and Bradley's *Our World Changes*, Ginn and Company.

1. Less than 5 per cent of all the children are suffering from the effects of malnutrition.
2. The appetite is a reliable guide to the selection of food.
3. At present there are over five hundred known organic compounds.
4. Most organic compounds are insoluble in water.
5. Organic compounds are not as active chemically as inorganic compounds.
6. Gasoline is composed of a mixture of several compounds of the methane series of hydrocarbons.
7. Glycerin is an alcohol.
8. Acetic acid is an inorganic acid.
9. Fat is an organic ester.
10. Digestion is a process by which food is made soluble.
11. All food must be dissolved before it can be absorbed into the blood stream.
12. The formula for protein is $C_6H_{12}O_6$.
13. The proteins in plant and animal food are identical with those in the human body.
14. Minerals provide the body with energy.
15. Vitamins aid in the regulation of body processes.
16. Water is not considered a food nutrient.
17. The protein molecule is much heavier than any inorganic molecule.
18. Carbohydrates are produced in a plant through a process known as photosynthesis.
19. Glucose does not have to be digested in order that it may be absorbed into the blood stream.
20. Maltose, or malt sugar, is sweeter than glucose.
21. Cellulose aids in the elimination of waste matter from the body.
22. Common fats, such as lard, tallow, and olive oil, are mixtures of fatty esters.
23. It takes all the 92 elements to make up the chemical structure of the body.
24. All elements are mineral elements.
25. All vitamins have now been discovered.
26. The small intestine is capable of doing a complete job of digesting carbohydrates, fats, and proteins.
27. Only about 50 per cent of the digestible food which is eaten is digested.
28. Any excess digested protein is thrown off by the body as waste matter.
29. A person who does not want to gain weight can eat all the protein he wants without increasing his weight.
30. Carbohydrates may be stored in the body.
31. All proteins are of equal value in building and rebuilding tissue.
32. Lean meat is pure protein.
33. Glucose in the body which is not used to provide energy may be converted into fat.
34. Mineral salts are stored in the body.
35. Mineral salts regulate muscle and nerve activity.
36. Copper is a constituent of thyroxine, which is secreted by the thyroid gland.
37. Vitamin A is generally supplied to the body by green and yellow vegetables.
38. Vitamin A may be manufactured in the body.
39. Vitamin A has no value in building up the resistance of the body to infection.
40. Vitamin B helps to stimulate the appetite.
41. Citrus fruits are good sources of vitamin C.
42. Vitamin D is found in many foods.
43. Vitamin-D cosmetics are helpful in supplementing the vitamin D obtained from foods.
44. Vitamin D controls the deposition of calcium and phosphorus in the bones and teeth.
45. Everyone should take the vitamin capsules which are now being advertised and sold.
46. There is no evidence to prove that the body may be harmed by an excess of any of the vitamins.
47. Vitamin E, under certain conditions, is known to have stopped hemorrhages, including internal bleeding.
48. Energy is necessary in the building of new tissue and the repairing of old tissue.
49. The energy required by a person does not depend upon his size and weight.
50. An athlete requires more energy from food than an office worker.
51. The energy value of many foods is not known.
52. The best food source of vitamins is green, leafy vegetables.
53. Too much salt in the diet may cause an excessive strain on the kidneys.
54. Water is the best source of minerals.
55. Overweight, or fatness, is always due to an excessive amount of food.
56. Most advertised diets for reducing are deficient in the energy-producing foods.
57. Proteins and carbohydrates should not be eaten together.
58. It is much more likely that a diet will be deficient in vitamins and minerals than in proteins, carbohydrates, and fats.
59. The variety of food we eat today is less than that of fifty years ago.

B. The statements which follow are incomplete. On a separate sheet of paper write whatever is necessary to complete the statements correctly. Do not write in this book.

1. Organic chemistry may be defined as the study of --(?)-- compounds.

2. When heated to a high temperature organic compounds --(?)--.

3. Hydrocarbons contain only the elements --(?)-- and --(?)--.

4. The formula for methane is --(?)--.

5. The carbon atoms of organic compounds always have a valence of --(?)--.

6. An alcohol in organic chemistry may be likened to a --(?)-- in inorganic chemistry.

7. The formula for grain, or ethyl, alcohol is --(?)--.

8. An ester is formed when an organic --(?)-- reacts with an --(?)--.

9. The six food nutrients are --(?)--, --(?)--, --(?)--, --(?)--, --(?)--, and --(?)--.

10. Digestion involves both a mechanical and a --(?)-- process.

11. Chemical substances which act as catalytic agents in the digestion of food are called --(?)--.

12. Protein digestion involves breaking down the complex protein molecules into simpler, soluble --(?)-- acids.

13. Carbohydrates are organic compounds composed of carbon, hydrogen, and --(?)--.

14. The formula for glucose is --(?)--.

15. All carbohydrates except cellulose are changed to --(?)-- in the digestive process before they are absorbed into the blood stream.

16. The chemical name for cane or beet sugar is --(?)--.

17. Excess glucose in the body is changed to glycogen and stored in the --(?)--.

18. Lactose is found in human --(?)--.

19. The formula for starch is --(?)--.

20. A fat is an ester produced by the reaction between a fatty acid and --(?)--.

21. The final digestive product of fat is --(?)--.

22. The digestion of --(?)-- begins in the mouth.

23. The enzymes in the stomach will not do their work unless --(?)-- is present.

24. The oxidation of glucose takes place through the catalytic action of --(?)--.

25. Mineral salts regulate the movement of --(?)-- from one body tissue to another.

26. A deficiency of --(?)-- in the diet may cause the disease goiter.

27. The manufacture of --(?)-- in the body is made possible through the action of the ultraviolet rays of the sun.

28. The energy value of food is measured by a device called the --(?)--.

29. A food calorie is the amount of heat necessary to raise --(?)-- pounds of water --(?)-- ° F.

C. On a separate sheet of paper write the letter or letters of the correct answer or answers. Do not write in this book.

1. A formula which shows the arrangement of the atoms in the molecule is called (*a*) an empirical formula (*b*) an atomic formula (*c*) a structural formula (*d*) a basic formula.

2. The formula of an organic acid always contains the radical (*a*) SO_4 (*b*) COOH (*c*) C_2H_5 (*d*) OH.

3. In the cells of the leaves of green plants is a substance called (*a*) stomata (*b*) enzymes (*c*) esters (*d*) chlorophyll.

4. A carbohydrate insoluble in water is (*a*) cellulose (*b*) starch (*c*) fructose (*d*) galactose.

5. Vitamin D may be produced in some foods through a process known as (*a*) electrolysis (*b*) irradiation (*c*) photosynthesis (*d*) ergosterol.

D. On a separate sheet of paper write together the number of each disease or condition of the body in Group II and the number of the vitamin in Group I whose deficiency may cause that disease or condition.

Group I

1. Vitamin A
2. Vitamin B_1
3. Vitamin C
4. Vitamin D
5. Vitamin E
6. Vitamin G, or B_2

Group II

1. Rickets
2. Scurvy
3. Beriberi
4. Sterility
5. Pellagra
6. Night blindness
7. Hemorrhages
8. Gray hair

REFERENCES FOR FURTHER READING

Bauer, W. W. *Health Questions Answered.* The Bobbs-Merrill Company, Indianapolis, 1937.

Bogert, L. Jean, and Porter, Mame T. *Dietetics Simplified.* The Macmillan Company, New York, 1937.

Clendening, Logan. *The Balanced Diet.* D. Appleton-Century Company, Inc., New York, 1936.

Fishbein, Morris. *Modern Home Medical Adviser.* Doubleday, Doran & Company, Inc., New York, 1935.

Fishbein, Morris. *Your Diet and Your Health.* McGraw-Hill Book Company, Inc., New York, 1937.

Malmberg, Carl. *Diet and Die.* Hillman-Curl, Inc., New York, 1935.

Morell, Peter. *Poisons, Potions and Profits.* Knight Publications, Inc., New York, 1937.

Rose, Mary Swartz. *The Foundations of Nutrition.* The Macmillan Company, New York, 1937.

Sherman, Henry C. *Chemistry of Food and Nutrition.* The Macmillan Company, New York, 1933.

Sherman, Henry C. *Food and Health.* The Macmillan Company, New York, 1938.

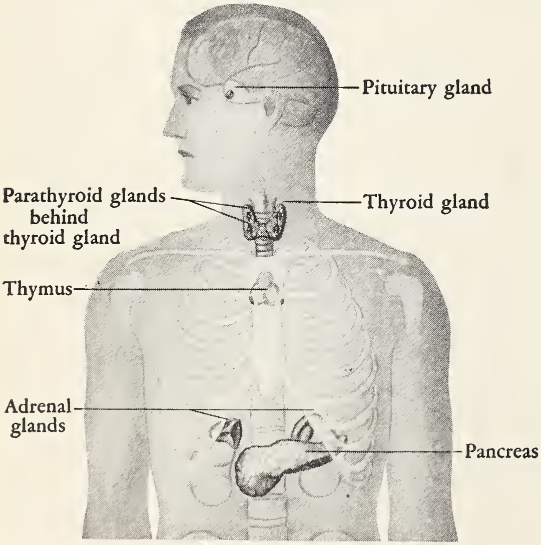
UNIT 13

Glands of Internal Secretion

Have you ever watched a workman operate a trip hammer? If so, you have probably marveled at the intense energy of the huge hammer as it moved in its downward path. Have you ever considered how much effort was required of the workman to release this energy? Actually it takes no more than that which is needed to pull a small trigger with one finger. This trigger, of course, releases a control which sets the hammer free so that its energy of position may be expended in doing a huge piece of work.

The trigger action of a trip hammer is comparable to the way in which the body functions are controlled by glands. Your ductless, or endocrine, glands secrete only minute amounts of chemicals, called hormones. Yet these secretions are powerful in their control of body processes. Very small amounts may determine whether you are a giant or a dwarf, fat or thin, nervous or calm, intelligent or imbecile, and many other conditions which are of fundamental importance to every living person. The field of chemistry and medical research relating to glands and their hormone secretions is one of the newest. Knowledge of the great importance of glands has spurred on research which will eventually result in some of the greatest contributions that science has ever made to the well-being of mankind.

The location of the glands of internal secretion[1]



Not a great deal is known about the glands—certainly not enough. Hormones have been isolated, and some have been synthesized in the laboratory. The functions of some of the glands have been discovered; yet no one knows whether these functions are the only ones. Some methods of gland treatment have been devised, but there are still many conditions that cannot be controlled.

PURPOSES TO BE ACHIEVED

1. To realize the relationship between normal glands and good health.
2. To recognize certain conditions of the body caused by the improper functioning of the glands.
3. To understand the effect that gland secretions have upon body functions.
4. To appreciate the possibilities of controlling certain body processes through the use of gland secretions.

PROBLEMS TO BE SOLVED

1. What are the ductless glands?
2. What are hormones?
3. What should you know about the endocrine glands?
4. What modern uses are being made of hormones?
5. What is the value of preparations which are essentially gland extracts?

Problem 1. What are the ductless glands?

Three classes of glands. In this discussion we are primarily interested in the glands of internal secretion, known as ductless glands. However, it will be well to classify all the glands of the body.

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[1] From Andress, Goldberger, and Hallock's *Helping the Body in Its Work*, Ginn and Company.

Our glands may be divided into three classes: (1) those which secrete substances through tiny ducts which lead to various organs of the body, (2) those which pour their secretions directly into the blood stream without the aid of ducts, and (3) those which secrete their substances both with and without the aid of ducts.

Several of the glands of the first class have been studied in connection with digestion. You will recall that the salivary glands (secreting saliva) and the gastric glands (secreting gastric juice) pour their secretions into the mouth and stomach, respectively, through ducts. There are many other duct glands in the body.

The second classification of glands comprises those which pour their secretions directly into the blood stream. This type of gland contains a network of blood capillaries into which the hormones pass. Among the most important of these glands are the pituitary, thyroid, parathyroid, adrenal (or suprarenal), pineal, and thymus. These are the glands of internal secretion, or the endocrine glands.

There are several glands in the body which secrete hormones into the blood stream and at the same time have an external secretion which is carried by ducts to particular organs. The pancreatic gland belongs to this classification. You will recall, from the study of digestion, that the pancreas secretes the pancreatic juice through ducts which lead to the small intestine. In addition, another part of this gland secretes insulin, a hormone, directly into the blood stream.

EXERCISES

1. Name and describe the three classes of glands.
2. Name some of the glands which are known as the ductless glands.

Problem 2. What are hormones?

Hormones are chemical substances. As has been previously stated, hormones are chemical substances secreted by the glands of internal secretion. The fact that these glands secrete only small amounts of these chemicals has led most authorities to believe that the controlling action of the hormones is catalytic. For example, it is estimated that the thyroid gland secretes only 3½ grains (480 grains = 1 ounce) of its hormone per year, which is too small an amount to be effective in any other type of chemical activity than that of catalysis.

Wide World

Sir Frederick Banting, who, with his associates, was the first to extract insulin from the pancreas of animals and to make it available for the treatment of diabetes. He was killed early in 1941 in an airplane crash

Another important characteristic of hormones that should be understood is that, although the amount secreted is small, the hormones exert a powerful control. It is estimated that the body rarely contains over ¼ grain of thyroid hormone at any one time. Yet this amount, though small, may make the difference between imbecility and normal intelligence.

In addition, there seems to be a definite relationship between the various ductless glands through their hormone secretions. The secretions of several of the glands are known definitely to have an effect upon the functioning of other glands. Experiments have been performed in which the pituitary glands of several immature animals have been removed. In each case the thyroid gland failed to develop properly, and hence the secretions of thyroxine became insufficient. When the pituitary extract was injected into these animals, the thyroid gland developed and secreted normally. The complete linkage between glands is not known, but knowledge is gradually being added through continued research.

In all animals a particular gland seems to produce the same hormone or hormones. Thus the hormone of the thyroid gland of a sheep is identical with that produced by the thyroid gland of a man. This fact has been very useful in that whenever a hormone cannot be made synthetically, it is possible to obtain it from the gland of some animal.

From this discussion it is evident that there are four principal properties and characteristics of hormones, as follows:

1. The amount of each hormone present in the body is very small.
2. Hormones exert a powerful control over body processes through a catalytic action.
3. There is a direct relationship between the hormones of the various ductless glands.
4. A particular gland produces the same hormone or hormones, regardless of the animal in which the gland is found.

EXERCISES

1. What are hormones?
2. Is the amount of each hormone in the body at any one time large or small? Give an example.
3. Does each hormone have an independent function? Explain.
4. Why are hormones taken from the glands of animals valuable?
5. How powerful are hormones in their control over body processes?

Problem 3. What should you know about the endocrine glands?

Glands control body processes. The solution of this problem will necessitate answering the following questions:

1. What is the function of each ductless gland?
2. What abnormal conditions may result if these glands do not function properly?
3. What can medical science do to overcome these abnormal conditions?

A consideration of this problem can best be undertaken by a discussion of each endocrine gland. As each of the ductless glands is discussed, the questions above should be kept in mind.

The pituitary gland. The pituitary gland is a small gland, about the size of a hazelnut, lying at the base of the brain. It is attached to and is hanging from the base of the brain by a slender stalk. This gland is composed of three lobes, the anterior, middle, and posterior. Although it is probably one of the most widely studied of the glands, there is much that is not known about it. It appears to produce hormones which stimulate almost all the other endocrine glands. For this reason it is sometimes referred to as the master gland.

Anterior lobe. This part of the pituitary gland secretes several important hormones. One of these hormones is known to possess the power of regulating growth. A deficiency of this secretion causes stunting of growth; children who are affected grow in perfect proportion and are normal in every way except size. An oversecretion of this hormone causes gigantism in young people. You have probably read of several cases where young people have reached a height of seven or eight feet. Such an abnormal condition is generally due to an oversecretion of this particular hormone. In the case of adults, an excess secretion of this hormone causes the bones to enlarge and become coarse, especially the bones of the hands and feet. The ends of the bones become large and prominent, and the jaw is frequently lengthened, causing wide spaces between the teeth. This condition, produced by this hormone, is known as acromegaly. An oversecretion of this hormone is frequently caused by a tumor on the pituitary. The closeness of this gland to the brain and the difficulty of getting at it make an operation very hazardous. An undersecretion which produces a stunting of growth can be taken care of by the use of the growth hormone obtained from the pituitary of animals. The use of this hormone is effective only if treatments begin at an early age. Gains in height varying from $1\frac{1}{2}$ to 6 inches have resulted from such treatments.

The possibility of increasing the height of a child whose growth has been stunted by factors other than a deficiency of this hormone is very doubtful. There is some evidence to show that growth produced in an individual beyond what is normally to be expected may not be desirable.

Another hormone of the anterior pituitary lobe is related to extreme overweight. A deficiency in the secretion of this hormone usually results in a type of "freak" that you have frequently seen in circus side shows—the fat lady or the fat man. The exact cause of such a condition is not fully understood, but it is known that a tumor on the pituitary, which also presses upon the brain, has sometimes been responsible for this abnormality.

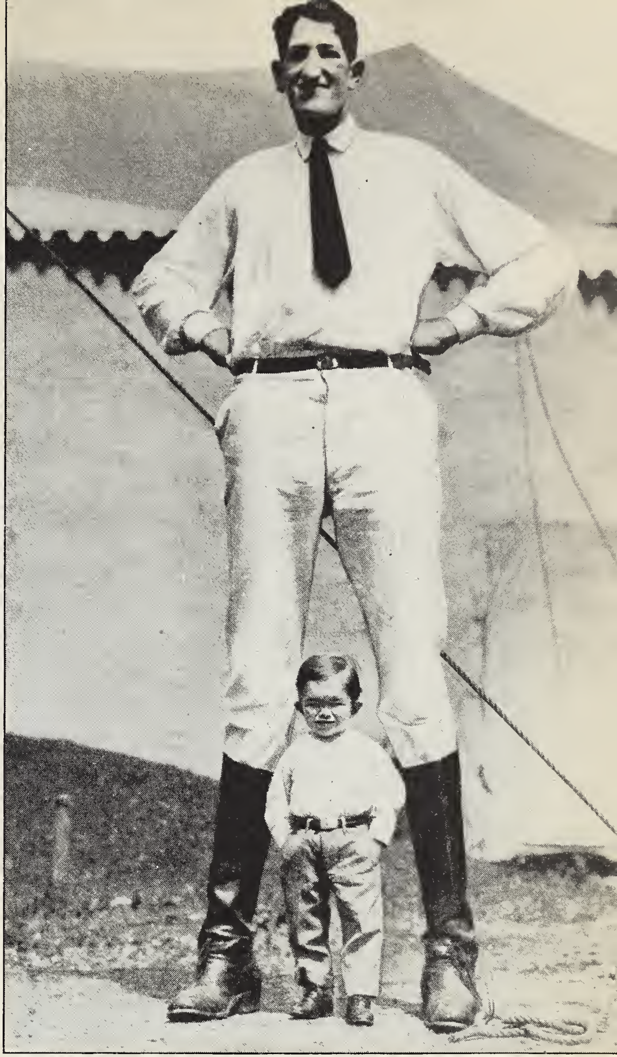
The middle and posterior lobes. These two parts of the pituitary are considered together because, so far as is known, the middle lobe produces several internal secretions and the posterior lobe stores them. One of the secretions from this lobe has been extracted from the gland in pure form and is now being used by physicians under the name of "Pituitrin." This secretion seems to control the texture and pigmentation of the skin, blood pressure, weight, water excretion, muscular contraction and relaxation, and sexual development.

Where an undersecretion occurs, the skin becomes smooth and soft. One of the hormones, when injected into a grass frog, caused its skin to become dark. An oversecretion causes an increase in blood pressure, and an insufficient secretion causes children to become fat. This fat appears in extraordinary places. The wrists and ankles generally remain thin, and the fat is deposited on the hips and thighs. An excess secretion may also cause a contraction of the passage through which the urine is excreted. The hormone which causes this contraction is now being used to regulate the secretion of urine in cases of diabetic patients, so that the elimination of sugar may be held to a minimum.

The thyroid gland. This gland is located in front of the lower part of the trachea (or windpipe). It has the general shape of a capital H and has an average weight of 1 ounce.

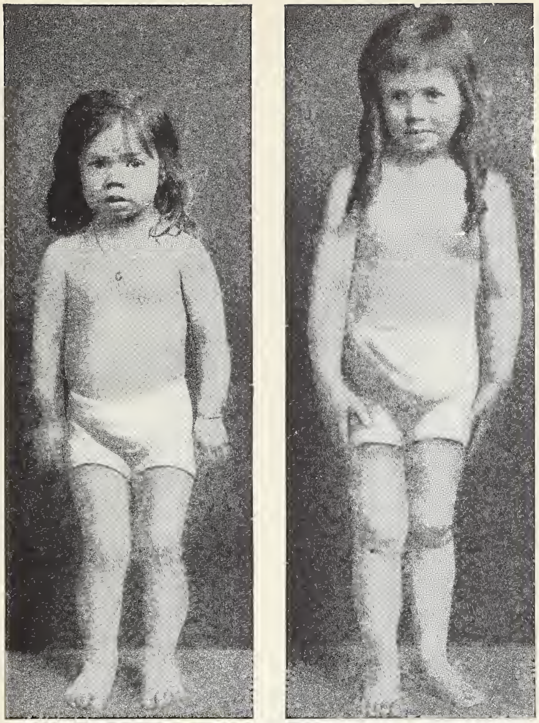
The thyroid gland secretes only one hormone, which is called thyroxine. The principal function of this hormone is that of the regulation of metabolism; that is, it regulates the speed at which food is assimilated by the cells of the body. Experiments show that the amount of thyroxine present in the body at any time rarely exceeds $\frac{1}{2500}$ of an ounce.

When the food which is eaten by a person does not contain enough iodine, the thyroid gland cannot manufacture the amount of thyroxine required by the body. With this hormone deficiency there is generally an enlargement of the gland, which is known as *simple goiter.* If this type of goiter is detected at the proper time, a complete cure can often be made. The use of iodized salt, sea foods, and vegetables grown in sections where iodine is present in the water is helpful in curing, as well as preventing, this type of goiter. Enlargement of the thyroid gland is more common in women than in men.



Ewing Galloway

The unusual tallness of the one man and the very short and undeveloped body of the other, a midget, are probably due to improper functioning of the thyroid and pituitary glands



These pictures are of the same child, one taken when she was a cretin and the other after treatments with thyroxine. Notice the improvement in physical development and facial expression[1]

A deficiency of secretion may also result if the gland itself is abnormal. This abnormality is generally hereditary and is caused by a deficiency of iodine in the diet over several generations. A child born with an underdeveloped thyroid fails to grow and develop; he becomes fat and thick-skinned, and his behavior is sluggish and indifferent. His mentality will not permit training, and he grows up ugly and idiotic. Where a deficiency of thyroxine on the part of the mother has occurred, the child is usually dwarfed and is called a cretin. Whenever such a condition is caused by the thyroid gland, treatment by the use of injections of thyroxine has been very beneficial. In the hands of a skilled physician a child so affected can be made a normal individual.

A thyroid deficiency many times occurs in persons fully grown, and is known as myxedema. In such a case the person becomes fat, the skin dry, and muscular and mental activity sluggish. This condition may also result in an improper functioning of other glands, which generally causes a still greater loss of efficiency. The injection of thyroxine based on scientific tests is effective in overcoming such a condition.

An excess secretion of thyroxine results in *hyperthyroidism*, which is a condition in which there is a too rapid oxidation, or burning, of food. A person so affected is always hungry; and although he eats a great deal, he loses weight and becomes thin and restless. The heart rate increases, the eyes bulge, and a general state of nervous tension is evident. The face is flushed, and the victim is extremely irritable. Such a condition is often referred to as exophthalmic goiter, which may or may not be accompanied by an enlargement of the thyroid.

Overactivity of the thyroid is generally treated by one of two methods, surgical operation or X-ray treatment. Through surgical operation portions of the gland may be removed, and thereby the production of thyroxine lessened. X-ray treatments have a tendency to cause the gland to decrease in size, with the effect of decreasing the secretion of the hormone.

Thyroxine has the formula $C_{15}H_{11}O_4NI_4$. It consists of approximately 60 per cent iodine. Although it was first thought that this hormone, when it was given artificially, had to be injected directly into the blood stream, it is now known to be effective when it is administered through the mouth.

The parathyroid glands. The parathyroid glands, which generally occur in pairs, vary in number from two to twelve and are found in contact with the lower portion of the thyroid gland and directly behind it. They are small, about the size of a grape seed, weighing 2 grains, and are yellowish brown to reddish brown in color.

The hormones of the parathyroid glands regulate the deposition of calcium in the bones and the amount of it present in the blood. You will probably remember that vitamin D shares in this function. If these glands are removed, a person can live but a short time.

[1] From N. B. Foster, "Diseases of the Thyroid Gland," in *Nelson Loose-Leaf Living Medicine*, Vol. III, by permission of Thomas Nelson & Sons.

A deficiency of the parathyroid hormones results in an insufficient amount of calcium in the blood. This may cause softening and bending of the bones, inability of the blood to clot fast enough, and a jumpy condition of the muscles. If this condition, which is known as tetany, continues, convulsions and death will result. Treatment consists of the injection of the parathyroid hormones into the blood stream of the patient.

A tumor on one or more of these glands may cause an excess secretion of the hormones. In such a case, the amount of calcium in the blood becomes greater. The excess calcium is obtained by the blood from the bones. This results in a brittle condition of the bones to the extent that they break from the slightest jar; and when they break, they fail to heal properly. In addition, the muscles become sluggish, rheumatic pains develop, and a shrinkage in height is noted. Treatment involves the removal of the tumor or the removal of one or more of the glands.

The adrenal, or suprarenal, glands. The two adrenal glands are shaped like cocked hats and are perched snugly each on top of a kidney. They are yellow in color and weigh from 4 to 5 grams each. Each of these glands is composed of two parts, the medulla, the central part, which secretes adrenalin, or epinephrine, and the cortex, the outer part, which secretes cortin.

Ewing Galloway

When an athlete puts forth all his energy and strength, he is being assisted automatically by his adrenal glands

The hormone adrenalin ($C_9H_{13}O_3N$) seems to have a controlling effect upon the sympathetic nervous system. Under conditions of stress, such as fright, anger, or excitement, the release of adrenalin into the blood steam is greatly increased and serves to reinforce the activity of the nervous system, placing the body in condition to meet the demands of situations involving great effort. In addition, remarkable changes in bodily functions result. Digestion is suspended, surface blood vessels contract, and the blood supply to the muscles is greatly increased. The sugar in the blood is abruptly increased, with a release of energy which may result in a maximum performance of the muscular system. Other physiological effects are a pale face, cold hands, and a rapid pulse; the hair stands on end, and frequently beads of perspiration appear.

When a cat becomes frightened, its hair stands on end. This is because of the sudden increase in the secretion of adrenalin. This also explains why men sometimes perform superhuman feats when greatly excited. You have probably read newspaper accounts of people who, in the excitement of a fire, have carried very heavy articles from a burning building.

When an undersecretion occurs, the person may be said to be "without nerves and emotions." Such a person can be rendered normal by the injection of adrenalin into the blood stream, provided these injections are continued through life.

The fact that adrenalin is a heart stimulant has made it a very valuable drug when quick stimulation of the heart is necessary. You have probably read accounts of people who have been brought back to life after death by the injection of adrenalin directly into the heart.

Experimental evidence tends to prove that animals are able to live without the medulla of the adrenal glands. On the other hand, destruction of the cortex results in death. It is now known that the adrenal cortex produces a hormone which is necessary to the well-being of the body.

A disease which is known to be caused by improper functioning of the cortex is Addison's disease. Such conditions as tuberculosis of the adrenals and tumors on the adrenals seem to be the cause of this disease. The symptoms of this disease are loss of appetite, body weakness, susceptibility to fatigue, feeble circulation, deepening of the color of the skin, fainting spells, scanty discharge of urine, and anemia. Unless treatment is begun early, death generally results. Treatment consists of the injection of cortin extract, which is obtained from the adrenal glands of animals.

The secretion of the adrenal cortex also exerts a direct control over the reproductive system. Evidence of this function has been noted in the fact that this portion of the adrenal enlarges during pregnancy. Moreover, the appearance of certain male characteristics in a female are noticeable when a growth forms on the gland. Several cases have been known of girls' developing hair on the face. When a tumor was removed from the cortex, the hair disappeared.

The pineal gland. The pineal gland, a tiny conical mass of tissue, is located between the two halves of the brain. Very little is known about the exact function of this gland. The secretion of the pineal is believed to influence the development of the brain and reproductive organs. It is also supposed to retard undue bodily growth. When a tumor forms on this gland, a child sometimes grows a beard and shows other signs of adulthood.

The thymus gland. This gland, sometimes called the sweetbread, is situated behind the breastbone. It is fully formed at birth; but after a child is two years old, the thymus shrinks gradually and becomes less active. At puberty it attains its minimum size and is practically worn out. This gland possibly regulates the oncoming of puberty.

As with the pineal gland, the function of the thymus is not fully understood. The thymus hormone, when injected into rats, produces a remarkable development, causing rats a few days old to appear to be a month old. In addition, the injection of this hormone into adult rats causes an increase in the rate of growth of their offspring which lasts for several generations.

The thymus gland is rarely abnormal. In a few isolated cases where the gland had become enlarged, the child affected was thin, dull, and weak, and failed to develop the proper habits of behavior.

EXERCISES

1. For each ductless gland discuss fully (*a*) its function in the body, (*b*) the abnormal conditions which may result from an oversecretion or an undersecretion of its hormones, and (*c*) what medical science can do to prevent and cure these abnormal conditions.
2. Locate and describe each of the ductless glands.

Problem 4. What modern uses are being made of hormones?

Experimentation reveals new uses for hormones. Experiments have been and are now being carried on with animals in an attempt to discover the effects of undersecretions and oversecretions of hormones and methods of controlling them. This experimentation has also included the injection of the various hormones into animals for the purpose of observing any biological changes which might occur in the animals. The results of such experimentation have given medical science much knowledge which can be used in the treatment of human beings who have glandular disturbances. Gland treatments, when applied to human beings, must be carried on with extreme caution because not all the results of animal experimentation can be used safely and successfully in the treatment of human beings. Such experimentation has resulted in the discovery of new uses for the hormones. Some of these uses will be of interest to you.

Adrenalin, which is now manufactured in the laboratory, has been found valuable in stopping excessive bleeding from wounds, including those of surgical operations. It is also used to stimulate the heart, reduce congestion of the nasal passages, and relieve sufferers from asthma. Insulin has recently been found valuable in the treatment of dementia praecox (a type of insanity) and for the relief of diabetics. "Pituitrin" is used as an aid in childbirth, to expel gas in the intestines, and to regulate the excretion of urine in diabetics.

These and many other uses are being made of gland extracts. An increased knowledge of the powerful influence of these chemicals upon body functions will undoubtedly unearth new uses which will be of great value to mankind.

EXERCISES

1. How is experimentation with the use of hormones carried on?
2. What are some of the new uses of hormones which have been discovered through experimentation?

Problem 5. What is the value of preparations which are essentially gland extracts?

The use of gland extracts may be harmful. There are many gland preparations which are being widely exploited. The unfortunate thing is that as the knowledge of hormones increases, the sale of extracts by quacks and charlatans will correspondingly increase. Do not be surprised if, in the future, you see claims that a gland extract will make you tall or small or will give you a perfect personality.

For years it has been known that thyroxine increases the rate of metabolism and that an excess of it will carry the process far enough to destroy cells and consequently reduce weight. There are several obesity (excessive fatness) remedies on the market at the present time which contain thyroxine. Such advertised preparations are all very dangerous, and their use should be discouraged. Serious consequences, often death, have been the result of the use of such preparations. In the hands of a skilled physician thyroxine is very useful in the reduction of weight, but in the hands of an amateur it may undermine a person's health permanently.

The tremendous influence that hormones have upon body processes makes their indiscriminate use very dangerous. To allow patent-medicine vendors to sell these drugs as means of regulating size, etc. is a practice which should be declared unlawful. To place hormones in the hands of a novice is comparable to allowing a child to play with nitroglycerin. Certainly the use of such powerful chemicals should be limited to specialists who have made an intensive study of the human mechanism, with special emphasis upon the glands.

EXERCISES

1. What dangers are connected with the use of gland extracts?
2. What gland extracts are now being sold indiscriminately?
3. Why do such products appeal to many people?
4. How should gland extracts be used? Why?

PROBLEMS FOR FURTHER STUDY

1. Prepare a report on the treatment of diabetes with insulin. Present your report to the class.
2. Consult your family doctor about the newest developments in gland treatments. Tell the class about your findings.
3. Write a report on the effects of gland secretions on personality.
4. Make a further study of abnormalities caused by gland secretions.
5. Choose one gland for a detailed report on its functions, the effects of oversecretion and undersecretion, and the means of treatment.

UNIT EXERCISES

A. Some of the statements which follow are true, and some are false. On a separate sheet of paper write the word *true* for those which are true and the word *false* for those which are false. Do nothing for those about which you are doubtful. Rewrite the false statements so that they are true.

1. Endocrine glands are those which secrete fluids through tiny ducts which lead to the various organs of the body.
2. Ductless glands secrete hormones.
3. The blood contains about one pint of thyroxine.
4. Each endocrine gland has a separate, independent function.
5. The hormones produced by the glands of animals are not the same as those produced by the glands of man.
6. The thyroid gland is composed of three parts.
7. The pituitary gland is called the master gland.
8. If a person is short in stature, he may become taller by having a physician inject a hormone from the pituitary gland into his blood stream.
9. Goiter may be inherited.
10. A deficiency in the secretion of the thyroid gland may cause a person to become overweight.
11. The thyroid gland may be removed without causing any ill effects to the patient.
12. The adrenal glands are located in the upper chest region.

13. The pineal gland gradually diminishes in size as a child grows older.

14. Gland experimentation has developed to the stage where it can be safely carried on with human beings.

15. Insulin is now being used to stop excessive bleeding from wounds, including those of surgical operations.

16. Thyroxine may be safely used by anyone who wants to decrease his weight.

17. It is almost impossible for a person to buy gland extracts today.

18. The government has passed laws which forbid the sale of gland extracts.

B. The statements which follow are incomplete. On a separate sheet of paper write the word or words which best complete each statement. Do not write in this book.

1. A hormone used as a quick heart stimulant is --(?)--.

2. Brittleness of the bones is often due to an excess secretion of a hormone of the --(?)-- glands.

3. Hormones are --(?)-- substances.

4. The small gland at the base of the brain is called the --(?)-- gland.

5. A deficiency of --(?)-- may result in simple goiter.

6. The parathyroid glands help to regulate the deposition of --(?)-- in the bones and teeth.

7. The phenomena of the hair standing on end and the performance of superhuman feats under intense excitement are due to a hormone called --(?)--, which is secreted by the --(?)- gland.

C. Each word or expression in Group II names a condition due to the improper functioning of one or more of the glands in Group I. On a separate sheet of paper write together the number of the gland in Group I and the number of the word or expression in Group II which best describes the condition due to improper functioning of that gland.

Group I

1. **Pituitary**
2. **Thyroid**
3. **Parathyroid**
4. **Adrenal**
5. **Pineal**

Group II

1. Softening of the bones
2. Premature adulthood
3. Beriberi
4. Goiter
5. Gigantism
6. Addison's disease
7. Scurvy

REFERENCES FOR FURTHER READING

Cobb, I. G. *Glands of Destiny.* The Macmillan Company, New York, 1928.

Crisp, Katherine. *Be Healthy.* J. B. Lippincott Company, Philadelphia, 1938.

Fishbein, Morris. *Fads and Quackery in Healing.* Blue Ribbon Books, Inc., Garden City, New York, 1932.

Fishbein, Morris. *Modern Home Medical Adviser.* Garden City Publishing Company, Inc., Garden City, New York, 1937.

Harrow, Benjamin, and Sherwin, Carl P. *The Chemistry of Hormones.* The Williams & Wilkins Company, Baltimore, 1935.

Hoskins, R. G. *The Tides of Life.* W. W. Norton & Company, Inc., New York, 1933.

Lobel, Joseph. *Medicine.* Farrar & Rinehart, Inc., New York, 1934.

Stieglitz, Julius, and others. *Chemistry in Medicine.* The Chemical Foundation, Inc., New York, 1928.

Sure, Barnett. *The Little Things in Life.* D. Appleton-Century Company, Inc., New York, 1937.

UNIT 14

The Chemistry of Disease

No living thing in this world exists without its natural enemies which tend to destroy it. Modern scientists and doctors believe that some of the natural enemies of mankind are the microscopic living things known as bacteria and protozoa, or, generally, as germs.[1] We know that these germs give off toxic substances which poison us, sometimes causing serious illness and sometimes death. But we have not always believed that germs cause disease.

The germ theory of disease is less than seventy-five years old. The great chemist Louis Pasteur is known as the father of the idea that germs can cause disease. Pasteur did most of his work during the latter part of the nineteenth century. However, other noted men had made discoveries before this time which undoubtedly helped Pasteur in his remarkable research. For example, we should remember Leeuwenhoek, the Dutch lens-maker, who in 1683 was the first man to observe, through his crude microscope, bacteria and protozoa. This visible proof of tiny living things was a necessary first step in the study of disease and probably made Pasteur's work possible two hundred years later.

The English physician and chemist Lister did much to further our knowledge of germs and introduced the use of chemicals which would kill them. Then, too, there was Robert Koch, the renowned German chemist, who paved the way for securing pure cultures of germs and the identification of them.

From earliest civilized times to the time of Leeuwenhoek, Pasteur, and Koch, many theories of the cause of disease had been advanced. Some authorities held that disease bodies germinated spontaneously within a person; some held that disease was the result of too much blood and that therefore the sick must be bled; others felt that sickness was a kind of punishment for committing sins; many believed that disease was due to a lack of balance of the humors, or liquids, of the body.

Though it is true that the germ theory of disease is now generally accepted by doctors and laymen and has replaced all the other theories, it must be remembered that there still remain some baffling diseases of which our best medical and chemical experts do not know the cause.

However, the development of the germ theory of disease has completely revolutionized most of the practice of modern medicine. From the time when Pasteur discovered that microorganisms cause the fermentation of fruit juices to the present, when research workers are able to prove that many kinds of germs cause different kinds of pneumonia, the chemist has played a most important part in helping man to stay healthy.

PURPOSES TO BE ACHIEVED

1. To understand the true nature of disease.
2. To gain a knowledge of how the body protects itself against disease.
3. To discover ways of maintaining a healthy body.
4. To learn about the tremendous cost of disease.
5. To gain an appreciation of the relation between chemistry and the control of disease and between chemistry and the prevention of disease.

PROBLEMS TO BE SOLVED

1. What is disease?
2. How does the body protect itself against disease?
3. What is science doing to protect man against disease?
4. What does disease cost?

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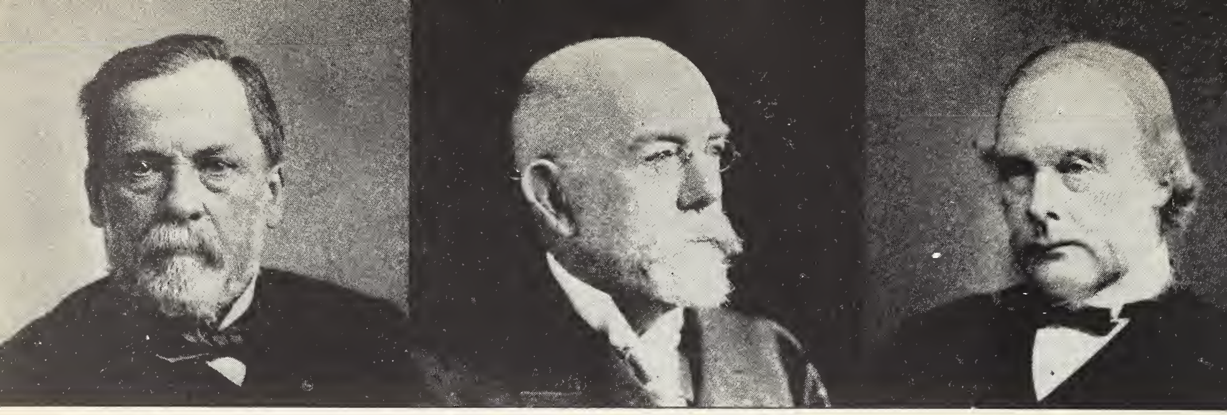
[1] The terms *germs* and *microorganisms* include both bacteria and protozoa. Bacteria are the smallest known forms of plant life. Protozoa are the simplest forms (one-celled) of animal life. Some bacteria and protozoa are harmful to the body, but many are beneficial.



Louis Pasteur, Robert Koch, and Joseph Lister. These three great scientists were pioneers in the fight against disease-producing microorganisms. What special contribution to medical science did each of these men make?

Problem 1. What is disease?

Germs produce toxins. Disease is generally regarded as any condition of the living body which prevents its normal functioning and its ability to live efficiently. Diseases can be classified as infectious, or contagious, and noncontagious. It has been definitely proved that most of the infectious diseases are caused and spread by germs, and it is with these diseases that we are mostly concerned in this book. There are other diseases, such as the common cold, which are thought to be infectious but whose germs have not yet been identified and isolated.

The illnesses caused by infectious germs are due to the toxic substances given off by the living germs as they thrive and multiply in the body. It is well known that every living thing gives off waste materials which must be removed from the living organism or else it will die. It is thought that the toxic substances produced by harmful germs are waste materials of the living germ cells.

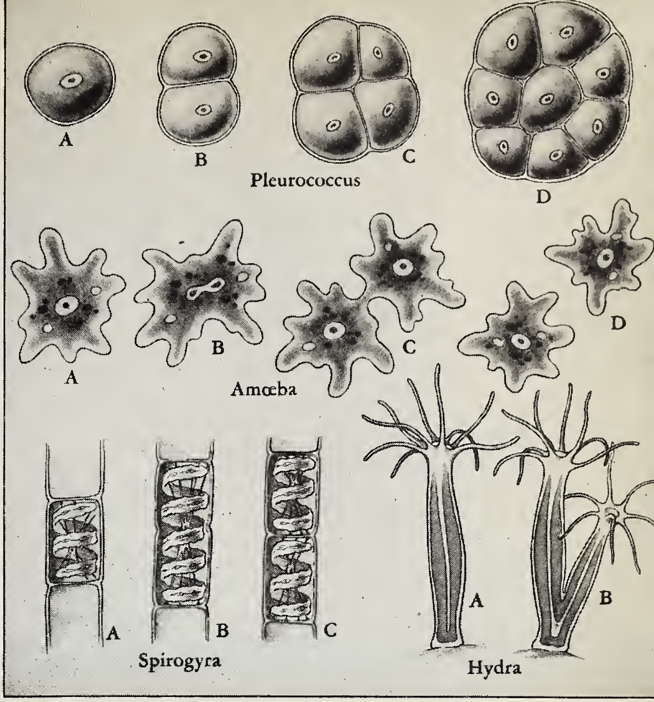
The study of bacteriology reveals that germs live only to eat and multiply. Everyone should realize that germs are not vicious creatures striving to kill human beings for their own enjoyment. Biologists tell us that the driving forces behind all living organisms are hunger and the urge to continue the life of the species. In living and reproducing themselves, some germs produce poisonous substances known as toxins, which substances are responsible for the diseases associated with these germs. In the majority of the diseases studied by biochemists, it has been found that the toxins liberated by the germs are merely incidental products of their life cycle. Other diseases are caused by the presence of the germs, even though they secrete no poisons.

Germs are found everywhere—in the deep ice-bound polar seas, in the tropical jungles, in the stratosphere, in distilled water, on fruits and vegetables, and in the bodies of plants and animals. Of course not all germs are harmful. Indeed, some are very beneficial and necessary to the health of people.

Germs and chemistry. The relationship of disease to chemistry can be shown in many ways. For one thing, it is believed that the toxins given off by germs are definite substances, although it has been impossible to determine accurately their chemical composition. Secondly, the treatment of a person infected with such toxic substances involves the use of specific chemical compounds. You will learn later of the ways in which the biochemists have made in their laboratories many new medicines to fight the toxins of harmful germs. The methods used in biochemical laboratories of studying germs, their growth and effect on the body, and the methods of control, all involve chemistry and chemicals.

How do germs increase in number? Germs multiply very rapidly when conditions are favorable to their growth. For the growth of germs to proceed at the maximum rate, the conditions under which they live should meet such requirements as darkness, plentiful moisture, sufficient food, and a temperature of from 95° to 100° F. You should recall that the normal temperature of the body is within this range, which accounts for the fact that the body makes an ideal place for many germs to thrive.

All germs reproduce, or multiply, by fission—



How one-celled animals and other microorganisms reproduce by fission

that is, by an automatic transverse division of the parent cell into two cells. In addition, some germs have other ways of multiplying. One of these is known as budding; that is, a small segment, or bud, forms on the outside of the parent cell which later may become an adult cell. Some germs produce specially resistant smaller cells. These are fitted to reproduce, after a long period of inactivity unfavorable to growth, the particular kind of germs that produced them. Such small cells are known as spores and have been known to resist long periods of drought and high temperatures but still retain the ability to grow into adult cells of the germs that produced them.

Ordinary fission, or division of cells, occurs very rapidly. The life span of some kinds of germs is as short as fifteen minutes; that is, one cell can grow to full size and split into two other cells in that length of time. A cell multiplying at that rate can produce 100,000,000,000,000,000,000,000,000,000, or 1×10^{28}, other cells in forty-eight hours if conditions remain favorable. Fortunately, conditions seldom remain favorable for any such rate of growth. Generally the toxins which are given off by germs as they grow and multiply are poisonous enough to inhibit their growth a great deal. The growth of germs is suspended entirely at temperatures near that of freezing water, and harmful kinds of germs are all killed at the temperature of boiling water, 100° C. Fortunately, most harmful germs perish at temperatures of from 50° to 70° C. This is a very important fact because foods containing germs may be heated to these temperatures and thereby made fit to eat.

Influence of Pasteur. Milk is an excellent medium for the propagation of germs, as it contains all the elements necessary to their growth. We can close the study of this problem with the thought that no greater monument has ever been erected to the work of a great man than that which has been erected to Pasteur in the laws requiring the pasteurization of milk. When we consider the millions of gallons of milk which are pasteurized every day in order to kill germs and thereby safeguard the lives of human beings, we realize how great has been the influence of Pasteur, the father of the germ theory.

Pasteur started us on the search for germs, and research into the problem of isolating them to discover ways to combat disease has been carried on since his day. The result has been the control of many diseases which before had been thought incurable.

EXERCISES

1. What is disease?
2. What is an infectious disease?
3. How do germs produce disease?
4. What are toxins?
5. How do germs increase in number? Explain fully.
6. What contributions did Pasteur make to the control of disease?

Problem 2. How does the body protect itself against disease?

The body resists the invasion of germs. The first thought that may come to you after reading the previous problem is that germs may eventually conquer and destroy mankind entirely, since germs are so prevalent and multiply so rapidly. However, you will discover that man is very well equipped to cope with these millions of invaders which may be harmful to him.

Most medical men agree that a perfectly healthy human body is all-powerful against disease germs which may attack the tissues. However, most people are not perfectly healthy all their lives. The ability to resist the invasion of your body by germs is known as resistance. There are many chemical factors which aid the body in building up and maintaining resistance to disease.

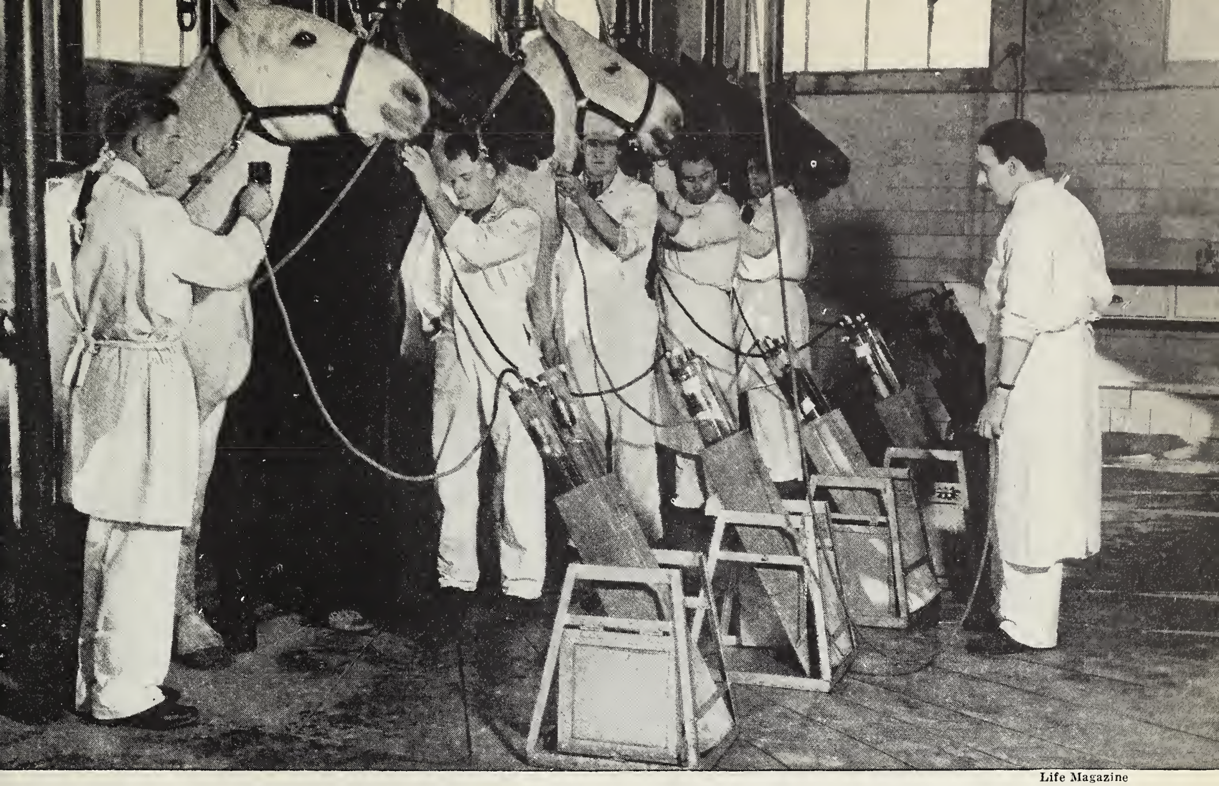
Antibodies, or antitoxins, and immunity. One of the most important protective agencies that each of us possesses is specific chemical agents known as antibodies or antitoxins. These substances are manufactured within various tissues when the need arises, that is, when the body is attacked by certain kinds of germs. The chemical composition of antitoxins has not been discovered. We know that they are substances which are probably related to the proteins, but no one antitoxin has ever been completely isolated. We recognize them by what they do rather than by what they are.

When germs such as those that produce diphtheria or tetanus invade the body, they find conditions ideal for their growth and immediately throw off poisonous substances known as toxins. The tissues of the body begin at once to manufacture the specific antitoxin which will neutralize or destroy these toxins. The infected person will survive if his body is healthy enough to produce sufficient antitoxin to conquer all the toxin which is being produced in his blood stream. The duration of his illness may be determined in large measure by the rapidity with which the antitoxin is manufactured within his body.

Chemists and biologists working together, by much experimenting with animals, have discovered ways to help mankind in this process. For example, they now know that a healthy horse may be injected with increasingly large amounts of the toxic diphtheria germs and that there will be built up in his blood stream abnormal amounts of the antitoxin which combats the toxins produced by the germs. Then some blood may be taken from the horse, and the antitoxin separated, purified, and prepared for use in human bodies. The antitoxin may then be injected into the blood stream of a person who has been exposed to diphtheria or who is suffering from the disease. Thus this person's blood will be fortified to an unusual extent, and, since his body does not have to make so much antitoxin by its own efforts, the disease either will not be contracted or will be very mild. After such treatment or at the termina-

An assortment of vaccines, serums, and antitoxins which are inspected by technicians at the National Institute of Health, research center of the Public Health Service. This important work of inspection is required by law. With such precautions being taken, physicians can be sure that the preparations may be used safely in the treatment of diseases

United States Public Health Service



Life Magazine

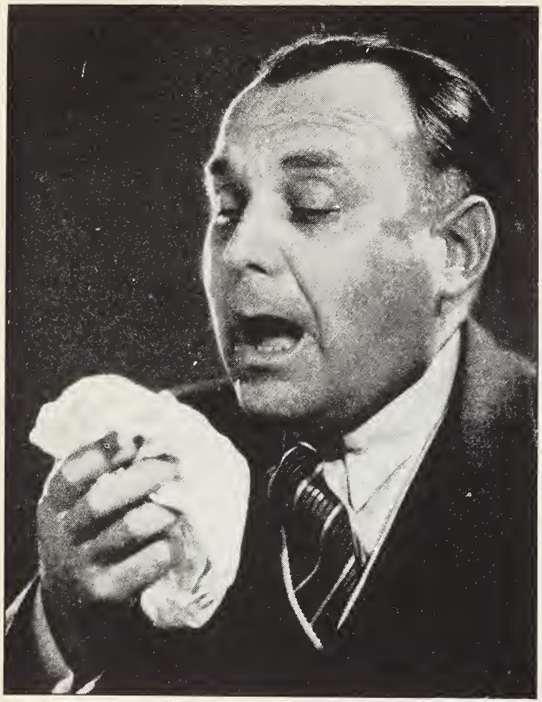
The blood being taken from these horses is used to make diphtheria antitoxin. The horses are unharmed

tion of the disease the body is said to be immune. Immunity to a disease is that condition in the body in which enough antitoxin has been administered or produced in it to cause it to be fortified against the disease.

Physicians immunize a healthy person against diphtheria by injecting into his blood stream a toxoid or a toxin-antitoxin. The diphtheria toxoid is a serum made by mixing diphtheria toxin with formaldehyde to weaken the toxin. Diphtheria toxin-antitoxin is a serum made by mixing diphtheria toxin with just enough antitoxin to nearly neutralize the toxin. With either serum the slight excess of toxin stimulates the body cells to produce the antitoxin which provides immunity to the disease. Toxoid, which gives immunity with one injection, has practically displaced toxin-antitoxin, which must be injected into the body three times at weekly intervals.

Immunity to various diseases may be acquired in more than one way. First, it may be acquired, as described above, by preparing the antitoxin in the body of an animal and then injecting it into the blood of a human being. Second, the living germs themselves or dead germs may be introduced into the blood stream, as in vaccination for smallpox, which causes the body to make the immunizing substance. While this is happening, the person experiences only a mild form of the disease. Third, immunity may be acquired by contracting the disease produced by germs and recovering from it. Immunity in this case is due to the antitoxin produced in the body by natural means, which neutralizes the toxins of the germs. In all these cases of immunity, the processes are essentially chemical processes.

Vaccines against colds. The disease known commonly as a cold is one that has baffled doctors for hundreds of years. No one knows the cause of the common cold, but it has been definitely proved that colds are contagious, and it is believed that they are caused by germs of more than one kind. Working on this theory, doctors have attempted to produce a vaccine which will serve as a protection against "catching cold." Cold vaccine is made by obtaining



Ewing Galloway

The common cold is a hindrance to healthful living. Medical scientists have been unable to find an effective method of curing colds

a mixture of the germs frequently found in the noses and throats of people who have colds. These germs are killed by exposure to heat, and the hundreds of thousands of dead bodies make up the material which is called a "cold shot" or cold capsule.

The effectiveness of "cold shots," or cold capsules, has not been accurately determined. There is evidence both for and against their effectiveness. One bit of evidence against their use seems to be the fact that having had a cold does not produce immunity to other attacks of colds. This would appear to indicate that the injection of dead germs will not produce immunity.

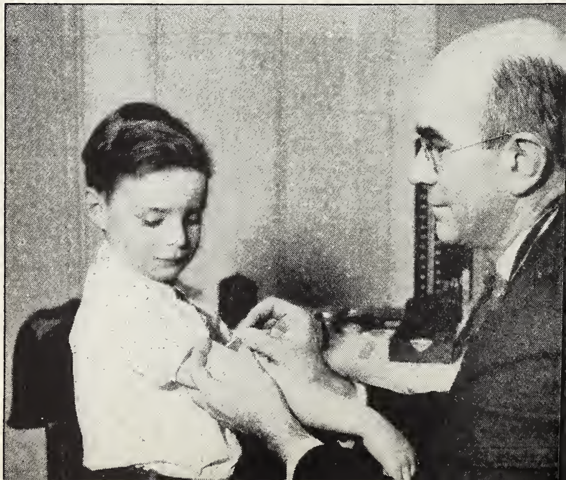
Factors which affect susceptibility to disease. You perhaps have discovered that not all people have the same ability to resist disease. A person's age is one factor that influences his ability to contract disease. For example, adults rarely have measles, whooping cough, and scarlet fever; yet children easily contract these diseases. One reason why an adult does not generally contract these diseases may be that his contacts with them when he was in excellent health in childhood enabled him, without his being aware of it, to build up gradually an immunity to them. An important factor which decreases resistance is excessive exposure of the body to hot or cold temperatures. A chicken which is made to stand in cold water will contract tetanus, a disease to which it is normally immune. A lack of proper food or extreme hunger and thirst have been demonstrated to be a cause of lowered resistance to disease. Also, fatigue is a cause. Animals which are normally immune to blackleg disease will contract it easily and die from it if they are first made to work or run until exhausted.

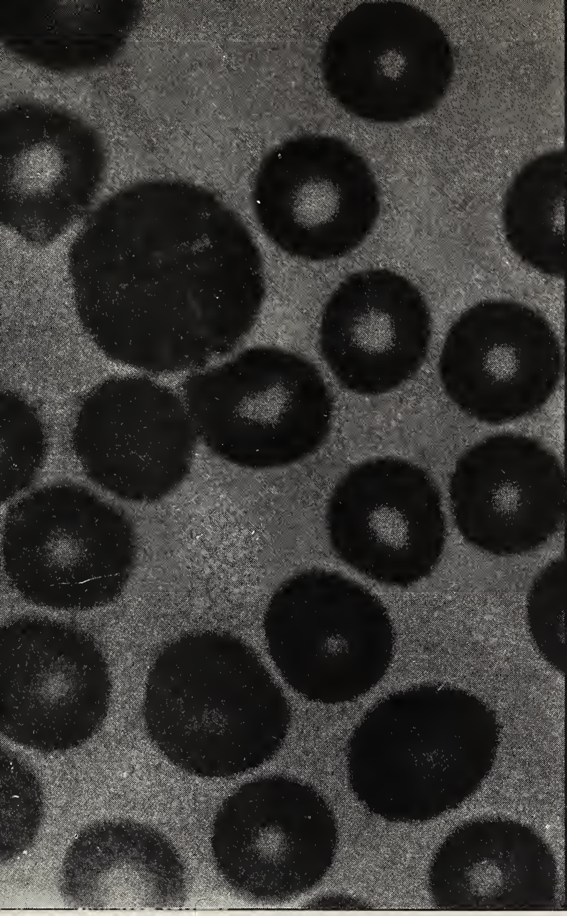
The body has other chemical defenses. The skin itself is protection against the entrance of germs into the body because of its thickness and also because of certain chemicals that are secreted by it. These substances are esters of cholesterol, which are fatty materials and have antiseptic properties. Infection of the skin will seldom occur unless it is ruptured in some way. However, germs will occasionally follow a hair down to its root and thus gain entrance into the tissues. This will cause an infection.

The hydrochloric acid (HCl) in the gastric juice is strong enough to kill most kinds of germs, and thus the body is protected against germs which may enter by way of the mouth. After partially digested food materials pass into the intestine, the acid is neutralized by the alkaline substances in the pancreatic and intestinal juices, and this medium is much more favorable for the growth of germs.

Many lives have been saved through immunization against disease

Ewing Galloway





Microscopic picture of a drop of blood. The red corpuscles are disk-shaped. The white corpuscle is large and irregular

Typhoid germs are here entering the blood stream. Some are being engulfed by the white blood cells and are thus destroyed[1]

Some kinds of germs that are not killed by the acid of the stomach would live were it not for the bile, which is also secreted into the intestine. Bile is antiseptic and will prevent the growth of most species of germs. The germs which cause the disease of typhoid fever and dysentery are not affected by these substances, and so we are particularly susceptible to these diseases.

The white blood cells as germ killers. Our bodies have other wonderful means of killing harmful germs which may get by the chemical defenses already described. In the blood there are always numerous white cells and wild-tissue cells which seem to possess the special property of feeding on harmful germs. This action is more biological than chemical, but the manner by which these cells are attracted to the scene of infection is a chemical process which is interesting to know. The action that takes place between the white blood cells and germs is really chemical warfare. If you study the field of battle with powerful microscopes, you will discover what looks like a real battle with large armies on both sides. The white cells and wandering cells come from all parts of the body to the spot where harmful germs are swarming to gain additional foothold. Since there is no physical or nervous connection between the white cells and the place of infection, the process which causes them to go to that spot must be chemical in nature. Biochemists believe that white corpuscles migrate to the germs because of the action of the toxic substances of the germs upon the white cells. When toxin strikes the sur-

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[1] From *The Book of Knowledge*, by permission of the publisher, The Grolier Society, Inc., New York.

Ewing Galloway

Nurse attending patient in fever-therapy cabinet. According to the Associated Press, doctors are working to cure various diseases with mechanically induced fevers. The patient lies in the fever cabinet from five to twelve hours. His head is out, and he is given water and various dosages to maintain normal body activity. Different germs die at different temperatures. Different people can stand different heats, depending on their age and general health. Almost anyone would suffer a heatstroke if his temperature went above 108.5° F, which is 9.7° above the normal temperature of the body. None of the temperatures employed is very uncomfortable at first, and the treatments would not be so severe if it were not for the length of time they require. A water bath at 110°, for instance, is pleasant. But if you remained in a tub at this temperature for an hour, physicians say, you would die

face of a white cell, it causes a lowering of the tension on one side and consequently the cell moves toward the germs. When the white cells strike the germs they engulf them, and in a short while the germs are completely destroyed. If the body has enough white cells, this action will continue until all the germs are destroyed. The body will then recover from the infection. There are countless minor infections of the body which go by unnoticed and unfelt because of the action of the white blood cells. A very severe infection or inflammation will be felt and noticed as an area of infection, and a substance which we call pus will form, which is really the accumulation of dead white cells killed on the field of battle.

The control of disease through proper diet. From all the foregoing information on immunology, it is evident that the general health of each of us is an important factor in combating disease.

We cannot have good health if we do not eat the proper foods so that our bodies can maintain the chemical defenses. To replace the worn-out white blood cells and to produce complex antitoxins require a diet which includes all the essential nutrients, especially vitamins. Disease and faulty diet go hand in hand, and the reverse is also true, namely, that health and adequate balanced diet go naturally together. In other words, good health is generally a matter of eating and living correctly. Many people overtax the chemical defenses of the body by failing to maintain healthful habits of eating and living. Education and the practice of what one has learned are the keys to health and to the conquest of disease.

Fever—a defense mechanism. Germs may get into the body in many ways. Sometimes the food we eat or drink contains them; the air we breathe always has some germs in it; open wounds may be left unsterilized too long; or the bite of an insect may provide the means for the entrance of germs into the body.

Often one of the results of the continued presence of germs in the body is an increase in the temperature of the body. Doctors call this increase fever. It is apparently due to the effects of the poisons of the germs on the nerves which control the temperature of the body.

There is considerable evidence to support the belief that, in many diseases, the increase in temperature is sufficiently high to stop the growth of the bacteria, so that we have in this process a natural device for the protection of the body against the disease. A doctor will not always try to reduce the fever of a sick patient, because he knows that it is one of nature's methods of controlling disease. If the fever is not much over 100° F and does not continue for too long a time, it is considered beneficial.

An animal inoculated with disease germs which cause a rise in temperature will soon die if its temperature is lowered by placing it in cold water.

This seems to be further evidence that fever is a protective device. One of the latest instruments that medicine has created is the fever-producing machine. It has not been tried sufficiently long to warrant extravagant claims, but it has been used with partial success in the treatment of some forms of insanity.

Rashes, or "breaking out." Some diseases, such as measles, are accompanied by a rash, or, as it is commonly called, a "breaking out." This is another way that the body has of protecting itself against disease, since, by this method, the poisons of the harmful germs are eliminated faster. In the case of measles, the patient will usually be most ill and have his highest temperature just before he "breaks out," which indicates that he is having a hard time eradicating the effects of the harmful germs. The patient quickly improves and his fever goes down after the rash appears.

For some diseases, the concentration of germs and their poisons is so great that they are always accompanied by a rash. However, some serious diseases do not break out in a rash.

EXERCISES

1. How do antitoxins, or antibodies, protect the body against disease?
2. How does the body produce antitoxins, or antibodies?
3. Describe a method employed by scientists to make antitoxins.
4. How may a person become immune to a disease?
5. How are cold vaccines made? Are they effective?
6. What factors affect susceptibility to disease?
7. What other chemical defenses does the body have to resist disease?
8. Describe fully how the skin, hydrochloric acid of the stomach, white blood cells, proper diet, and fever are defenses against the ravages of disease.
9. What causes rashes?

Problem 3. What is science doing to protect man against disease?

Scientists understand disease. Germs in the body produce disease in several ways. A disease may be due to the absorption of the poisons secreted by the germs or to the accumulation of great numbers of them in the blood or certain organs of the body. Regardless of the way the disease germs cause disease, it is the business of scientists, be they chemists, doctors, or biologists, to try to do three things:

1. To observe and understand how germs get into the body.
2. To develop methods of keeping them out of the body.
3. To develop medicines and materials which will kill the germs or prevent their growth.

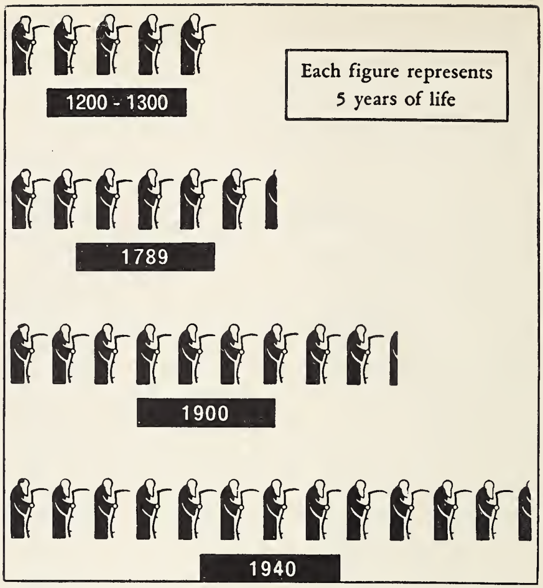
Scientists have attacked the problem of disease on the three fronts mentioned above, and the use of the scientific method of study has produced many gratifying results. For example, the discovery, after years of research, that the bite of a mosquito causes yellow fever enabled man to conquer this disease. The building of the great Panama Canal was possible because doctors were able to prove the connection between yellow fever and mosquitoes. Among other diseases which have been wiped out entirely, or partially conquered, because man has studied the means of the entry of germs into the body are bubonic plague, malaria, typhoid fever, smallpox, dysentery, tularemia (rabbit fever), lockjaw, rabies, or hydrophobia, and Rocky Mountain fever.

When the means of entry of germs into the body are not understood, as in the case of the disease infantile paralysis, prevention or control is very difficult. The whole science of the prevention of disease is based upon the knowledge of the ways by which infectious diseases gain entrance into the body. Absolute cleanliness in the care of those who are ill and on the part of those who are well is the master rule of prevention. Another excellent rule that the average person should follow to prevent disease is to keep up his resistance by eating a sufficiently well-balanced diet, by exercise, by resting healthfully, and by getting into the sunlight.

Scientists produce specifics. The scientific method of stating the problem, gathering evidence, and drawing valid conclusions based on experimental evidence has given us many specifics for the control or cure of disease. By "specifics" we mean substances such as serums, antitoxins, vaccines, and medicines which act on particular kinds of germs to kill them, prevent their growth, or neutralize their poisons. To discuss all the materials of this nature which have been discovered is beyond the scope of this book. However, many of you may wish to investigate this

General Electric Company

Dr. Irving Langmuir is shown here experimenting with a new method that he has developed to detect viruses, poisons, and toxins which may be suspected in liquids



From this graph you may determine the average length of life of persons who lived at different times in the past. Compare the average length of life in 1789 with that in 1940[1]

problem further. To aid you, a few such substances are mentioned here: smallpox vaccine for smallpox, tetanus antitoxin for lockjaw, hydrophobia vaccine for rabies, diphtheria toxin-antitoxin for diphtheria, and sulfanilamide derivatives for streptococci infection. Some other specifics produced by science are insulin for diabetes, glandular extracts for deficiencies of endocrine glands, aspirin for the relief of headaches and other pains, "Novocain" for anesthetic purposes, meningitis antitoxin for meningitis, and erysipelas serum for erysipelas.

The net result of the discovery of such substances has been the elimination of much suffering and death. Moreover, the average length of life has been raised, and the general happiness of every one of us has been increased. We owe much to the men and women who spend their time working with the molecules of substances which alleviate disease and promote health.

EXERCISES

1. What three things are medical scientists concerned with in their attempt to protect man against disease? Discuss the importance of each.
2. What are specifics?
3. Of what value are specifics?
4. Give examples of some important specifics which are now being used.

Problem 4. What does disease cost?

Disease is costly. The cost of disease in dollars and cents to the people of this country is very hard to compute. It is tremendous, but the exact amount cannot be determined because of the many factors involved. For example, think of the cost of maintaining the many hospitals throughout the nation. The public-health departments of our states and Federal government have individual budgets running into millions of dollars. Private hospitals and research organizations which study disease problems are maintained by endowments and private fees that total other millions. Moreover, the loss of productive time from jobs, when translated into money, rises to huge proportions. And many of our health institutions spend great sums in trying to prevent disease and in educating people to live healthful lives, which sums too form part of the cost of disease.

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[1] Reproduced from Curtis, Caldwell, and Sherman's *Everyday Biology*, Ginn and Company.

It is estimated by some authorities that the common cold costs the United States two billion dollars a year. No one knows how much it really costs in devitalized living, headaches, irritability, and inability to do the daily job well.

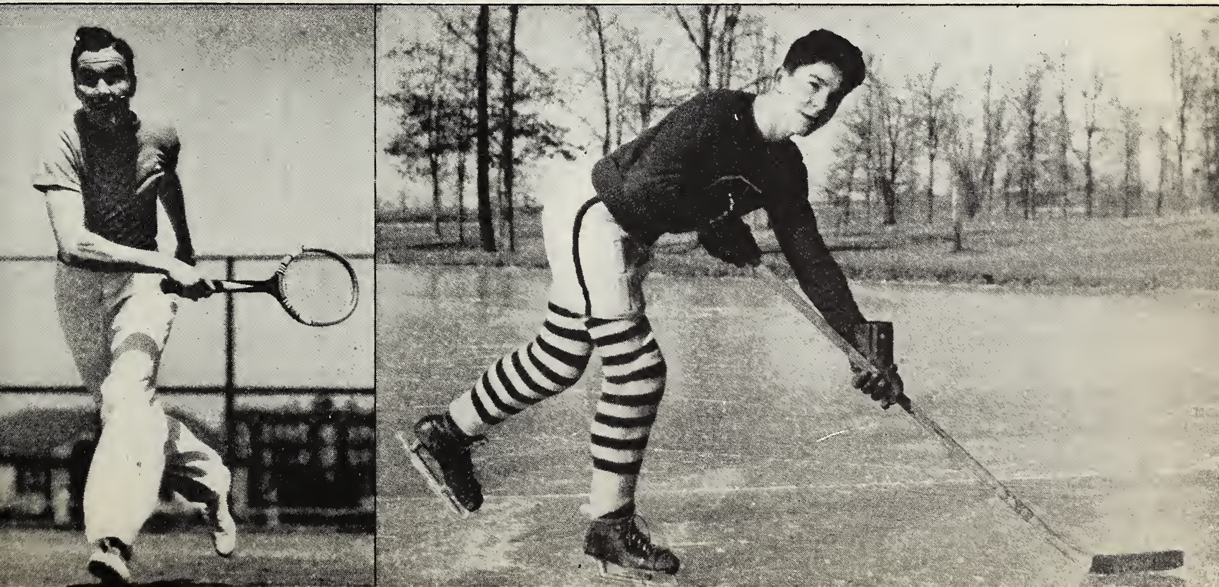
The United States loses some $250,000,000 yearly in animals from diseases which they contract.

From the foregoing, it should be evident that much of our public and private income goes to fight or prevent disease. And it seems that this will be true for a long time in the future, because new diseases are constantly coming to the fore and old diseases are constantly causing trouble in unexpected ways. We have made much progress in combating infectious diseases, and many that formerly took a heavy toll of men and money are now under control. We have checkmated them by sanitation, vaccination, use of antitoxins, and quarantine; but eternal vigilance is necessary to ensure that the old epidemics do not return. The absence of certain diseases over a period of time causes people to forget preventive measures, such as vaccination, and then the old disease rises again to epidemic proportions.

More specifics need to be produced by chemistry. The greater proportion of our control of disease is possible because of preventive measures. We really have too few cures for disease. We need more specific medicines similar to quinine, which is a specific remedy for malaria. The various compounds derived from sulfanilamide seem to offer a promising avenue of approach for chemists. Many such compounds are now being tried, and, if they are found to be effective against specific types of germs, they will reduce materially the ravages of disease.

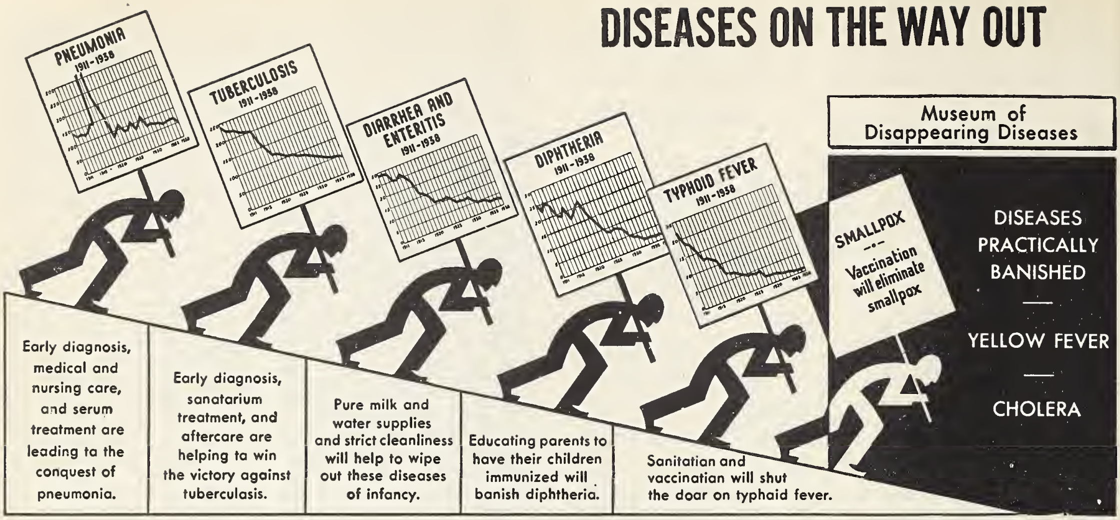
Childhood diseases are being gradually conquered, and our world is becoming more and more free from disease. However, some diseases, such as cancer, heart disease, and infantile paralysis, are increasing, and a great deal of research remains to be done if they are to be checked or conquered. Specifics for these diseases not only will reduce the cost of disease but will add to the length of life and the happiness of millions of people.

What is a high-school student's responsibility with regard to disease? Every student should feel individually responsible for assisting in the fight against disease. You can do this in several ways. Of first importance is the living of a well-balanced life with plenty of the right kind of food, plenty of outdoor exercise, and plenty of rest. This will give you that quality of resistance to disease which is all-important to health. Secondly, you can help by preventing people from becoming overconfident because of past success in the field of preventive medicine. You can assist in promoting the idea that immunization treatments are important, even though the disease may not have occurred in your community for many years.



One of the best means to good health is to engage in some outdoor recreation

Ewing Galloway



Metropolitan Life Insurance Company

Lastly, you may continue your study of the chemistry of medicine and aid in the control of disease by your own discoveries.

EXERCISES

1. Discuss fully the many aspects which cause disease to be costly.

2. What are some of the great needs in the fight against disease?

3. What part can you play in the fight against disease?

PROBLEMS FOR FURTHER STUDY

1. How do food and diet affect a person's resistance to disease?

2. What is the relationship between acid foods, basic foods, and disease?

3. Where are the most healthful places in the United States to live? Why is there a difference in the healthfulness of places?

4. Make a survey of the diseases in the United States to see how they rank as to their death rates. What diseases are on the increase? Which are decreasing?

5. What diseases are young people most susceptible to? most resistant to?

6. What other theories of the cause of disease exist besides the germ theory?

7. Make a study of the relationship between susceptibility to disease and races of people.

8. Write to the American Medical Association, Chicago, Illinois, and other health agencies to get information on the very latest substances which have been discovered for the prevention and control of disease.

9. What agencies in your own community are there for the control and study of disease? What do they do?

10. Are mental diseases caused by germs? If not, what are the causes?

11. Is an absolutely disease-proof community desirable? Why?

12. What vocations are open to young people who are especially interested in the study of health and disease? How long does it take to prepare for such vocations? What qualities should one possess to enter them?

13. What are the newest developments in the use of the sulfanilamide derivatives?

UNIT EXERCISES

A. Some of the statements which follow are true; others are false. On a separate sheet of paper write the word *true* for those which are true and the word *false* for those which are false. Write nothing for those of which you are doubtful. Rewrite the false statements so that they are true.

1. At some time in the future disease will be banished from the earth.

2. The fact that germs cause disease has been known for several hundred years.

3. Disease is generally regarded as any condition of the body which prevents normal functioning and ability to live efficiently.

4. Toxins are waste materials given off by living germs.

5. Germs live only to eat and multiply.

6. If germs multiplied rapidly, disease would be much more prevalent and severe than it now is.

7. Germs may reproduce by division of the parent cell into two cells.

8. Most germs perish at a temperature of 95° F.

9. Freezing does not destroy all germs but usually retards their growth.

10. The body is capable of manufacturing antitoxins, which destroy the toxins produced by disease germs.

11. Antitoxins should be injected into the blood stream only just before the contraction of the disease or during the time when a person has the disease.

12. Antitoxins are available for almost all diseases.

13. After a person has a disease, he is immune from having it again.

14. Cold vaccines are mixtures of the dead germs which cause colds.

15. It is desirable that everyone use cold vaccines.

16. Excessive exposure to hot or cold temperatures decreases the resistance of the body to disease.

17. The red blood cells destroy germs.

18. The proper kind and amount of food aid the body in building up a defense against disease.

19. Fever aids in destroying disease-producing germs.

20. In time almost all diseases will be cured through the use of a fever machine.

21. Rashes are evidence that there are bad humors in the blood.

22. Specifics are diseases of which the germs have been discovered.

23. Insulin is used to cure streptococci infections.

24. Disease in the United States costs about two million dollars a year.

25. Sulfanilamide compounds and derivatives seem to offer many possibilities in the control of disease.

26. Cold vaccines have proved to be very reliable specifics.

27. It is very important that scientists who are fighting disease know how the germs get into the body.

28. It is always desirable that the fever of a patient who is ill be reduced.

B. The statements which follow are incomplete. On a separate sheet of paper write the word or words which correctly complete each statement. Do not write in this book.

1. The father of the germ theory of disease is --(?)--.

2. Most --(?)-- diseases are caused by germs.

3. Illness caused by germs is due to --(?)-- substances given off by the bacteria as they thrive and multiply in the body.

4. The composition of toxins leads scientists to believe that they are definite --(?)-- substances.

5. The harmful germs in milk are destroyed through a process called --(?)--.

6. The stomach contains a chemical compound called --(?)-- which helps the body to resist the invasion of some germs by destroying them.

7. Substances such as serums, vaccines, and medicines which will act upon particular kinds of germs to kill them or prevent their growth are known as --(?)--.

REFERENCES FOR FURTHER READING

BAYNE-JONES, STANHOPE. *Man and Microbes.* Williams & Wilkins Company, Baltimore, 1932.

BUCHANAN, ESTELLE, and ROBERT, EARL. *Bacteriology.* The Macmillan Company, New York, 1931.

DE KRUIF, PAUL. *Men against Death.* Harcourt, Brace and Company, New York, 1928.

DE KRUIF, PAUL. *Microbe Hunters.* Harcourt, Brace and Company, New York, 1926.

FISHBEIN, MORRIS. *Frontiers of Medicine.* Williams & Wilkins Company, Baltimore, 1933.

FISHBEIN, MORRIS. *Modern Home Medical Adviser.* Doubleday, Doran & Company, Inc., Garden City, New York, 1935.

FURNAS, C. C. *The Next Hundred Years.* Reynal & Hitchcock, New York, 1936.

GREENE, R. L. *The Chemistry of Health.* R. L. Greene, Notre Dame, Indiana, 1928.

HEISER, VICTOR. *An American Doctor's Odyssey.* W. W. Norton & Company, Inc., New York, 1936.

STIEGLITZ, JULIUS, and others. *Chemistry in Medicine.* The Chemical Foundation, Inc., New York, 1928.

VALLERY-RADOT, RENÉ. *The Life of Pasteur.* Garden City Publishing Company, Inc., New York, 1930.

Hygeia. Bound volumes of this periodical may be had by writing to *Hygeia*, 535 North Dearborn Street, Chicago, Illinois.

Metropolitan Life Insurance Company. Health publications may be had by writing to the Metropolitan Life Insurance Company, New York.

UNIT 15

The Chemistry of Drugs and Medicines

The quest of good health is as old as man himself. Early men attributed disease and pain to evil spirits or the curse of the gods. To rid themselves of a disease, they tried everything from the weird rituals of medicine men to the drinking of vile-smelling and vile-tasting concoctions. These ceremonies and potions were designed to drive out the evil spirits, and even today many persons have more faith in a foul-tasting medicine than in one that is pleasant to the taste. "To be good, it must taste bad" seems to be an axiom of many patent-medicine manufacturers.

Occasionally some of the remedies prescribed by these early practitioners did relieve the patient, though we have no record of the thousands who were killed by these remedies. Man's desire to live on and on caused him to search continually for new remedies and medicines. The quest of the elixir of life and the fountain of youth led man to the four corners of the earth and caused him to experiment with many substances. The discovery of the element phosphorus in urine was one result of this search.

The remarkable advances made in modern medicine and surgery would not have been possible without the aid of chemistry. Since the body is essentially a chemical machine, a knowledge of the chemistry of bodily functions is essential to the physician and the biologist. Chemistry, then, has explained to the physician the processes which take place in the body and has furnished the material, the drugs and medicines, necessary to combat disease and relieve suffering.

The delicate operations performed by surgeons today would not be possible without anesthetics, which produce relaxation and unconsciousness or, at least, a deadening of the nerves in a particular area of the body. Fatal infection would result very often if the instruments and the wound were not made sterile with antiseptics. Indeed, the sharp, delicate instruments could not have been produced without the chemist's knowledge of special alloy steels.

There are a number of common chemicals used as drugs or medicines with which we should be familiar. In this unit it is not the purpose to present information which will enable you to diagnose illness and to prescribe medicines. That is the business of the physician. It is to be hoped that someday competent medical service will be available to everyone who needs it, and that everyone will consult a physician not only when there are symptoms of illness but periodically, even when he is feeling well.

PURPOSES TO BE ACHIEVED

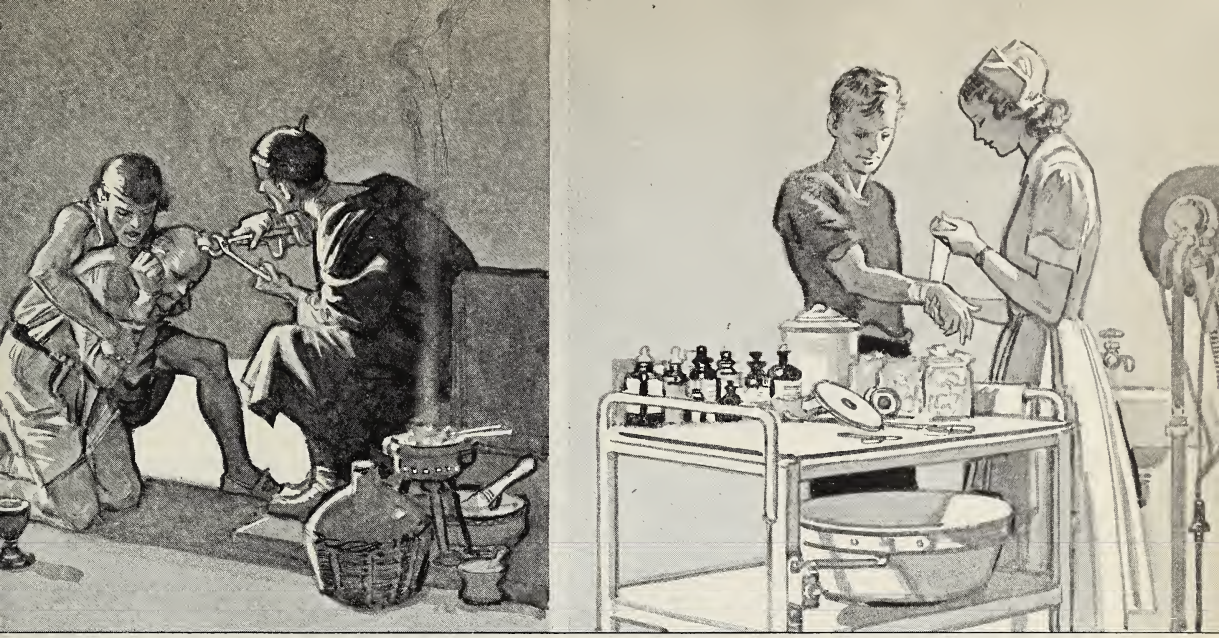
1. To learn the chemical nature of drugs and medicines.
2. To learn how to use drugs and medicines intelligently.
3. To appreciate how drugs and medicines have affected mankind.
4. To learn how to buy drugs and medicines economically and intelligently.

PROBLEMS TO BE SOLVED

1. What are the chemical composition and properties of each kind of drug or medicine?
2. What is the effect on the human body of each drug or medicine?
3. How may we intelligently use common drugs and medicines?
4. What factors should be considered in purchasing drugs and medicines?

The problems above will be discussed under each of the following classifications of drugs and medicines:

Antiseptics and disinfectants
Laxatives
Headache remedies and other pain-relievers
Burn preparations
Cold and cough remedies
Anesthetics, narcotics, and hypnotics
Stimulants



Many improvements in methods of controlling and treating diseases have resulted from the use of new drugs and medicines

Antiseptics and Disinfectants

When were antiseptics and disinfectants first used? Primitive man always associated disease with the supernatural; he attributed it to the displeasure of the gods or to the entrance of some malign spirit. Very often he used aromatic or acrid substances to drive out the evil spirits. Indeed, sometimes he used burning sulfur. It is likely that often the serious spread of infection and disease was halted by such practices. Often primitive man left the place of disease because he thought it was bewitched, and thus prevented the spread of infection.

It is interesting to note that though the Egyptians perfected the art of preserving the dead by disinfection, they did not connect this method of preservation with the cure of disease or the prevention of the spread of disease.

In the early nineteenth century numerous attempts were made at disinfection. In one instance, in 1808, a physician in England ordered that all sleeping quarters of ships be frequently whitewashed. However, there was a somewhat obstinate opposition on the part of the medical profession as a whole to new ideas of disinfection. In spite of this, the use of disinfectants gained steadily.

As early as 1843 chlorine water was used as a disinfectant. Phenol, silver nitrate, and iodine are mentioned in the literature of that period. Though the microscope had been invented by Leeuwenhoek in 1676, and mention was made of small "living animalcules" in water, nothing of importance developed for years. It was almost 1850 before any study was made of germs by use of the microscope. Between the years 1860 and 1864 Louis Pasteur, the French chemist, proved that certain diseases of beer and wine were caused by the presence of wild yeast plants. As you have already learned, his subsequent work on germs, particularly his work on anthrax and rabies, brought about one of the greatest advances in the science of disinfection.

The work of Louis Pasteur came to the attention of Joseph Lister of England, who began employing a solution of carbolic acid, or phenol, in the disinfecting of surgical wounds. Lister is often called the father of clean surgery, for he insisted that cleanliness was one of the best safeguards against the spread of infection after surgery.

Today there are many disinfectants and antiseptics on the market for home use, and many methods of disinfection are practiced by physicians and hospitals. A technique has been developed of thoroughly sterilizing all surgical instruments, the hands and breath of attendants, and all the surroundings, so that the chances of infection during operations have been materially lessened.

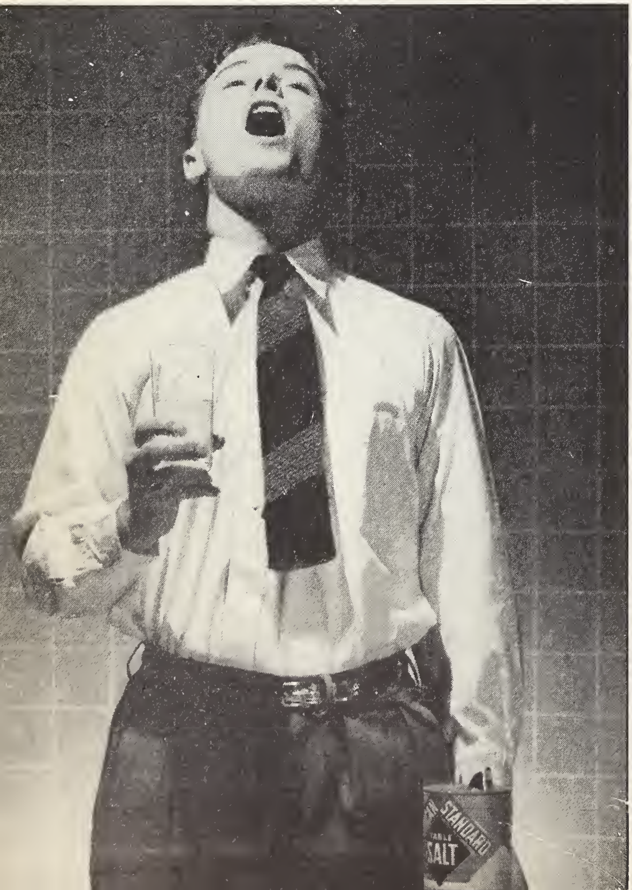
What are antiseptics and disinfectants? The term *antiseptic* is used to indicate any substance which will inhibit the growth of germs without necessarily killing them. A *disinfectant*, or germicide, is any substance which will kill germs. All three terms are often used loosely and sometimes interchangeably. A weak solution of phenol, or carbolic acid, may be classed as an antiseptic, while a stronger solution is certainly a powerful disinfectant.

Oral antiseptics. People have been made "antiseptic-conscious" by a continual barrage of radio and magazine advertisements. We are made to believe that we are no better than those of the Dark Ages if we do not wash our mouths, our hair, and our bodies with the latest discoveries in antiseptics.

It has been scientifically demonstrated that many of the popular mouthwash antiseptics, when diluted in the mouth, possess no germ-killing power. But even those that do possess this power cannot reach many crevices in the mouth and teeth. In addition, the antiseptic is in the mouth too short a time to be effective. Then, too, the breath is continually being drawn through the mouth, bringing millions of the same germs back into the mouth. Some mouthwash antiseptics make excessive claims as to their germ-killing power. If you must have a mouthwash, a teaspoonful of table salt in a glass of water will prove more effective than expensive, highly flavored mouthwash antiseptics.

A solution of salt in water makes a good oral antiseptic

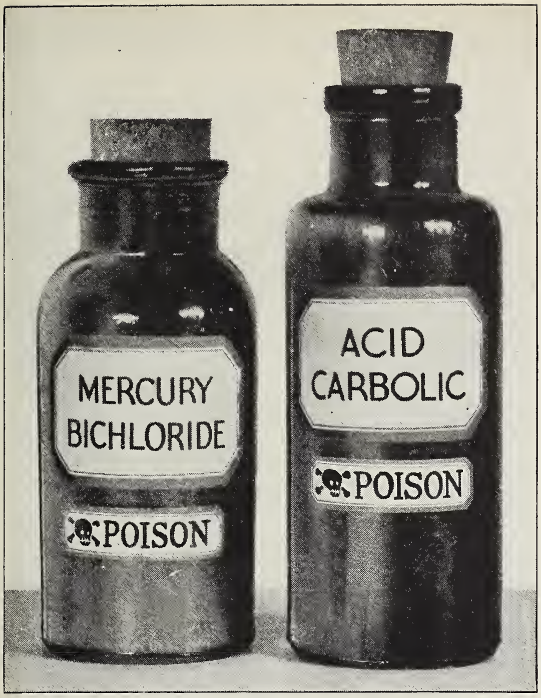
Ewing Galloway



The effectiveness of antiseptics and disinfectants against the various types of germs may be measured. To do this the germ-killing power of an antiseptic or disinfectant is compared with that of phenol, the standard disinfectant used for comparison. In the laboratory this is done as follows: A specific dilution, or concentration, of an antiseptic or disinfectant is placed with a specific kind of germ, such as *Bacillus typhosus*, until all the germs are killed. The ratio between this dilution and the dilution of phenol necessary to destroy the same germs in the same length of time is known as the phenol coefficient of the antiseptic or disinfectant. For example, if the phenol coefficient of iodine against a particular germ is 7, this means that a specific dilution of iodine is seven times as effective in destroying this germ as the same dilution of phenol.

What disinfectant may be used for minor cuts? There are a number of commercial disinfectants available for the self-treatment of minor cuts; one of the best, according to its phenol coefficient, is tincture of *iodine*. This disinfectant is made by dissolving crystals of iodine in alcohol. It is usually painted on with a toothpick or applicator stick wrapped with cotton. The solution of iodine should not be too strong, the wound should not be bound tightly, and the solution should always be allowed to dry thoroughly. A 3 per cent solution is the most generally accepted strength for home use. The bottle should not stand open, because the evaporation of the alcohol increases the strength of the solution. Serious burns may result if the solution becomes too concentrated.

Merthiolate has a high phenol coefficient and is another popular and effective disinfectant. It is a complicated organic compound, having the chemi-



Why is the medicine cabinet an unsatisfactory place to keep these disinfectants?

cal name *sodium ethylmercurithiosalicylate*. The formula is $C_2H_5 \cdot HgS \cdot C_6H_4 \cdot COONa$. It contains 49.6 per cent mercury by weight. Merthiolate may be purchased in either the aqueous (water) or alcoholic solution. The aqueous, or water, solution has the advantage of not stinging or burning, as the alcohol solution does; and the aqueous solution does not produce a stain, as the alcoholic does. However, alcohol itself is an antiseptic, so that the tincture of merthiolate is more effective.

Boric acid (H_3BO_3) is a mild antiseptic kept in many medicine cabinets. It is a white, odorless powder. One gram of the powder dissolves in 4 cubic centimeters of boiling water or 18 cubic centimeters of cold water. A saturated solution is commonly used as an eye antiseptic. A 1 per cent to 4 per cent solution is used as an oral antiseptic. It has a low phenol coefficient.

"*Mercurochrome*" is a complicated organic compound containing bromine and mercury. Its formula is $C_{20}H_8O_6Br_2N_2Hg \cdot 3\,H_2O$. It is an odorless, iridescent, green, granular solid which is quite soluble in water, forming a red solution. A 1 per cent solution is used as a mild antiseptic. The aqueous solution, which is commonly sold in drugstores, has a relatively low phenol coefficient.

Another disinfectant is *bichloride of mercury* ($HgCl_2$), or corrosive sublimate. It is a deadly poison and should never be kept in the family medicine cabinet. It is a white powder which is often compressed into tablets. Most states require that bichloride of mercury contain a green or blue dye, so that its solution will not be mistaken for water. After being used, the remaining tablets or solution should be carefully discarded.

Dressing a minor wound. It is necessary that the hands of a person taking care of any small wound be washed with soap and water until they are thoroughly clean. As an added precaution, it is then well to wash them in bathing alcohol, which is antiseptic. All materials applied to the wound should be sterilized. Such materials are now available in drugstores. Sterile gauze, cotton, and applicators should be in every home medicine cabinet. If these are not present, a freshly laundered handkerchief or towel is likely to be relatively free from germs. If small splinters are to be removed, the needle or

Every home should have readily available a first-aid kit for the proper dressing of wounds

Ewing Galloway

Ewing Galloway

This tourniquet is being correctly applied to stop the flow of blood when an artery is severed. How should it be applied when a vein is severed?

tweezers should be passed through a flame in order to kill all germs.

In dressing a wound, it is important that any germs that might have entered be killed and that all other germs be kept out. These are the steps which you should follow in dressing a wound: (1) Cleanse the wound and the skin around it thoroughly by pouring water over it and then washing the skin with a piece of sterile gauze which has been dipped in alcohol or a soap solution. Care should be taken, in washing, not to brush the germs on the skin into the wound. (2) Dry the wound by pressing it gently with sterile gauze. (3) Apply a disinfectant directly to the wound and to the skin around it. (4) Cover the wound completely with several thicknesses of sterile gauze and fasten the gauze to the skin with adhesive tape. Adhesive tape should not be placed directly on the wound, nor should it completely cover the sterile gauze.

You should not be alarmed at the bleeding of a minor wound, as this is a natural cleansing process. If there is profuse and continued bleeding, it may be necessary to apply a tourniquet.

Remember that first aid should not be last aid. If a wound does not respond to home treatment and an infection develops, a physician should be consulted.

EXERCISES

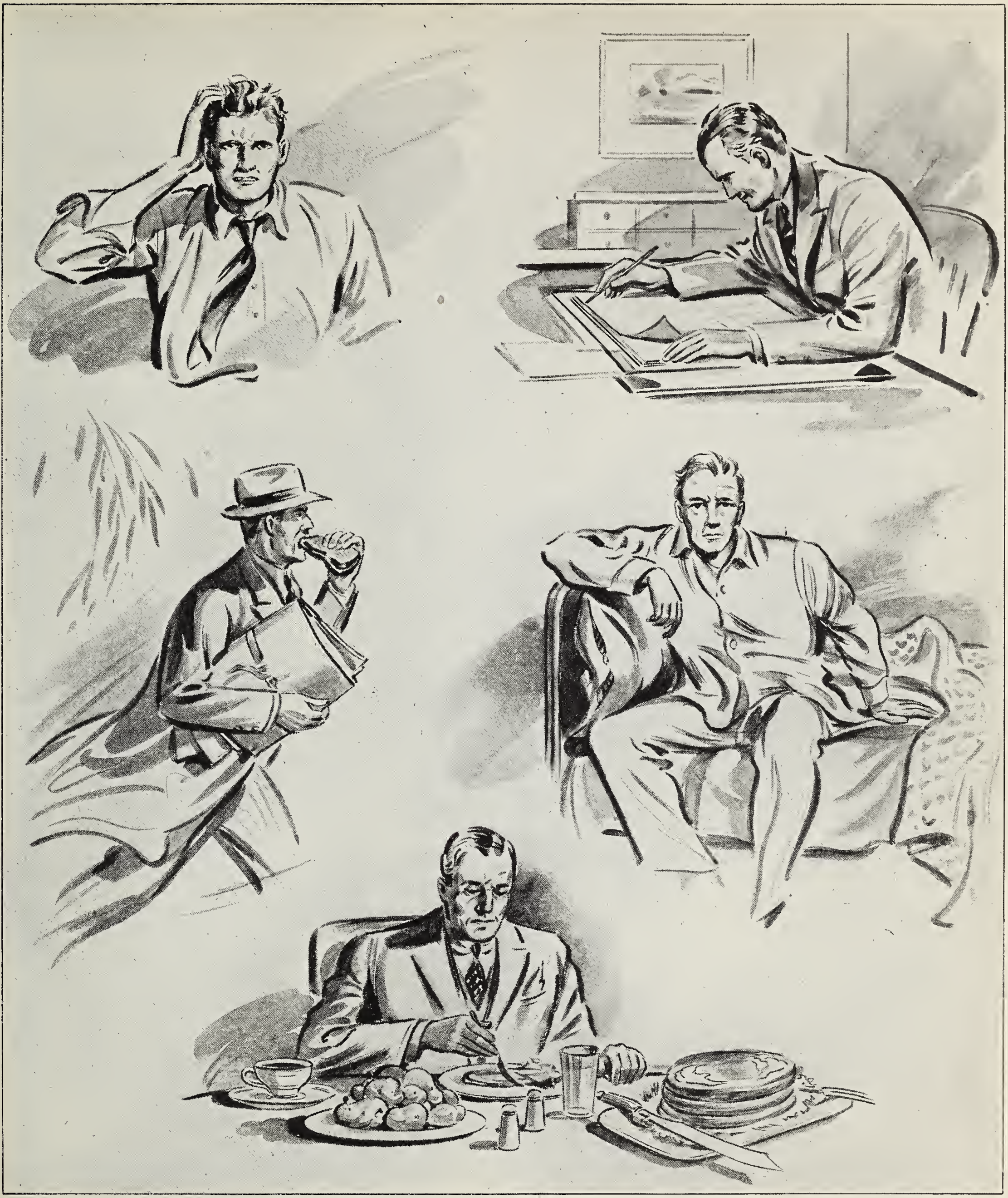
1. What men were the first to use antiseptics and disinfectants?
2. What were some of the first disinfectants used?
3. What is the difference between an antiseptic and a disinfectant?
4. Of what value is an oral antiseptic? Explain.
5. What is a good oral antiseptic to use?
6. What is meant by "phenol coefficient"?
7. Give (*a*) the chemical nature and (*b*) the value as a disinfectant of minor wounds of each of five commonly used antiseptics and disinfectants.
8. How should a minor wound be dressed?

Laxatives

The use of laxatives. An eminent physician recently said that the American people suffer from overdosages of cathartics and laxatives. Most families keep some laxative in the medicine cabinet to use for cases of constipation. Three terms are used to differentiate those chemicals, or medicines, which accelerate the passage of food refuse through the intestines. Laxatives are mild and are most often used. Cathartics are stronger in action; purgatives are strongest. These terms are frequently used interchangeably. Often the same medicine may be used either as a mild laxative or as a strong purgative by simply taking a small amount or a large amount of it.

Great care should be exercised in the use of laxatives, as there are circumstances under which they are exceedingly dangerous, particularly where there are symptoms of appendicitis. This disease is manifested first as a little infected area on the appendix. This organ is attached to the large intestine and apparently has no function in the body. The small infected spot may grow in size like a boil, and there is danger of its bursting and spreading the infection throughout the body. The spread of infection results in peritonitis, which is often fatal. Since laxatives cause unusual strain on the abdomen and intestines, there is danger that an infected appendix will burst. *Whenever there is extreme pain in the abdomen, no laxative should ever be taken. See a doctor!*

What causes constipation? There are many reasons why a person may become temporarily constipated, such as nervous strain, undue excitement.



Constipation may be caused by (1) worry, (2) inactivity, (3) poor eating habits, (4) insufficient sleep, or (5) insufficient or incorrect diet. What are some other causes?

irregularity of diet, bolting of food, lack of exercise, failure to pay attention to the desire for a bowel movement, undue sweating or fever, which reduces the amount of water in the residual waste material (feces), and failure to drink sufficient water. Moreover, the habitual use of laxatives is frequently a cause of constipation.

Temporary constipation may become habitual, or chronic, if one or more of the conditions stated above persist over a long period of time. This is due to the fact that the normal action of the intestines in eliminating waste matter becomes sluggish. The longer this condition exists, the more difficult it is to correct.

Constipation and health. Since constipation means that the residual material remains in the intestines longer than it should, there may be an excessive absorption of poisonous materials into the body, bringing about a loss of appetite, headaches, skin eruptions, and a pallor of the skin. Such persons sometimes have dizzy spells, ringing in the ears, dullness, and fatigue. However, there are many physicians who discredit the theory of the absorption of poison from the feces and who believe that many of the symptoms mentioned are due to other causes.

It is not necessary for a person to have a bowel movement every day. It may be normal for some people to have an evacuation every other day. However, whatever the frequency, there should be regularity. Undue alarm should not be felt if one passes the time for a regular bowel movement. The chances are that the body will readjust itself without outside aid if the normal diet and exercise are continued. Mineral oil or some other mild laxative may be helpful, but the regular use of laxatives is distinctly harmful. It is much better to observe carefully proper rules of exercise and diet than to depend upon artificial stimulation of the bowels.

How do laxatives work? There are five different types of laxatives, each bringing about the desired result in a different way. Some are very dangerous, while others are relatively safe. Each of these types will be discussed briefly, and the common laxatives of each type will be listed.

1. *Bulk-producing laxatives.* Agar-agar, psyllium seed, and bran cereals are examples of this type of laxative. They are usually given in the treatment of habitual constipation. If they are taken, the amount should be gradually decreased so that finally their use is discontinued.

Bulk-producing laxatives owe their effectiveness to the property of swelling, which increases the bulk of the feces. The swelling tends to fill the large intestine, producing peristaltic movements of the bowels and causing a desire for elimination. Peristaltic movement is a wavelike motion of the intestines produced by successive contractions of the muscular walls, which force the contents onward. Agar-agar is the least objectionable of this type of laxative. Some of the others are rough and may cause scratching and irritation. Agar-agar is a dried mucilaginous extract of a certain kind of seaweed found in the Orient.

2. *Lubricants: mineral oil and emulsions.*[1] Russian mineral oil and liquid petrolatum are examples of the lubricant type of laxative.

Lubricants are among the most popular laxatives. They are, when not emulsified, colorless, odorless, and tasteless fluids. They are not absorbed, digested, or acted on by germs, and are perhaps the least objectionable of the laxatives. Lubricants owe their effectiveness to the film of oil which coats the fecal particles, causing them to pass through the intestines with less friction. It is doubtful if much so-called Russian mineral oil actually comes from Russia, and consumers will find liquid petrolatum, U. S. P., just as effective. Many people depend upon lubricant laxatives to produce a bowel movement every day.

Anyone who becomes a constant user of lubricants or any other type of laxative should by all means see a physician, as the normal body requires no stimulant for elimination, and none should be used except in rare instances.

3. *Laxatives which stimulate peristaltic movements. a. Toxic drugs.* Most of the nerve-irritant type of laxatives contain the drug phenolphthalein, a very toxic substance which you have used in an alcoholic solution as an indicator. It is a coal-tar product, white in color, powder in form, and tasteless. Phenolphthalein is very active in small doses,

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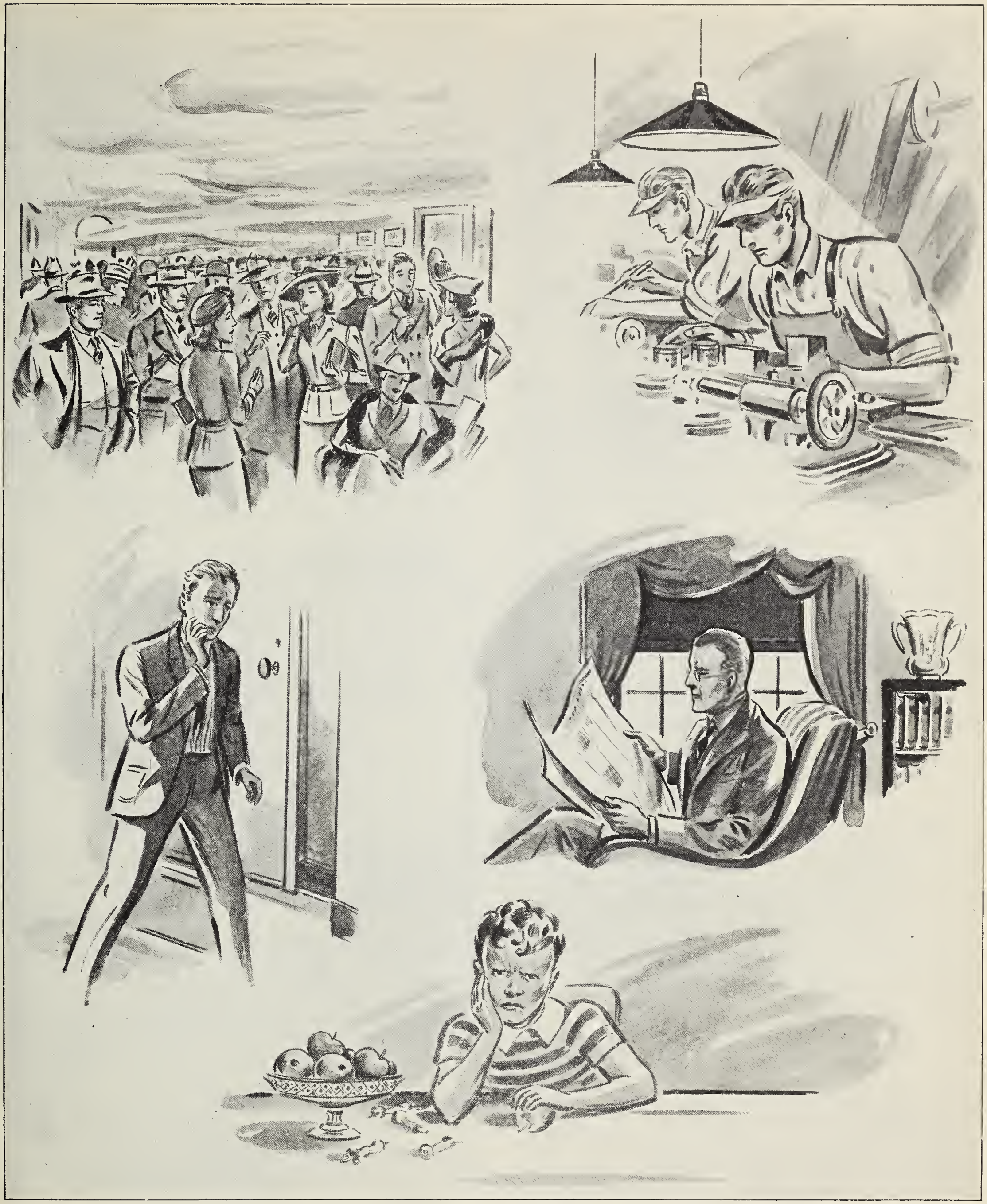
[1] When two liquids, such as mineral oil and a solution of agar-agar, are thoroughly mixed together so that the small droplets of one liquid are dispersed throughout the other, they form a milky suspension called an emulsion.



Some causes of headaches. Can you suggest others?

stimulating the nerves of the small intestine and colon, and causing peristaltic movements. It is included in many patent-medicine laxatives. Laxatives which contain phenolphthalein are often sugar-coated, mixed with chocolate, or included in chewing gum. Such laxatives have caused marked stomach and intestinal disturbances, rapid pulse, difficult breathing, collapse, and, in the case of some sensitive persons, ulcers of the mouth and skin eruptions. Laxatives that contain this drug tend to become habit-forming, and their use should be restricted.

Some laxatives, sold as patent medicines, contain strychnine, a potent poison. Such drugs have no place in the family medicine cabinet.

b. Vegetable nerve irritants. Cascara sagrada, sirup of pepsin, castor oil, and other vegetable laxatives owe their effectiveness to some vegetable compound, such as cascara or senna. Their presence acts as a nerve stimulant and produces peristaltic movements in the intestines.

Of this type, cascara sagrada is probably the safest laxative and is often prescribed in small doses by physicians as a mild laxative. If taken in large doses, it acts as a purgative. The medicine is an extract from the bark of a shrub or small tree called cascara buckthorn. It is found on the Pacific coast and elsewhere in the western United States. The preparations made from it appear as liquids, pills, and tablets. The most palatable form in which to take this laxative is aromatic fluid extract of cascara sagrada.

Castor oil is the oil extracted from the bean of the castor-oil plant, which is grown in the United States. It is a violent purgative and should not be taken except as prescribed by a physician. Castor oil is used only in extreme cases of constipation; and if there are any abdominal pains which may be due to appendicitis, it should not be taken.

4. *Saline laxatives.* Epsom salts ($MgSO_4 \cdot 7\,H_2O$), milk of magnesia ($Mg(OH)_2$), Seidlitz powders, sodium dihydrogen phosphate (NaH_2PO_4), magnesium citrate ($Mg_3(C_6H_5O_7)_2 \cdot 14\,H_2O$), and many of the mineral waters on sale throughout the country are all examples of saline laxatives. Their laxative property is due to the fact that they contain a salt which increases the density of the fluids of the feces. This causes water to be drawn from the surrounding tissues of the body, thereby increasing the fluidity of the feces and aiding their passage through the bowels. The greatest danger in this type of laxative or purgative is that there usually follows a period of constipation, which causes the user to think that more of the laxative should be taken. Many people become habitual consumers of mineral waters, which, in addition to causing habitual constipation, may bring about more serious disorders in the kidneys and bowels.

5. *Natural roughage.* Bran cereals, whole-wheat bread, and other rough and fibrous foods sometimes are taken by people as laxatives. They are dangerous for people with sensitive intestinal linings and may produce irritation and ulcers. They are supposed to stimulate peristaltic movements by providing bulk, but, at the same time, they may produce irritation. The normal human diet contains enough roughage, despite the cry that modern foodstuffs are lacking in roughage. Plenty of vegetables, fruits, and salads will provide all the roughage any person needs.

Normal living prevents constipation. Most people take laxatives to relieve constipation when, if they would give the body time, a natural readjustment would take place, and no ill effects would be felt. Many authorities assert that to go without a bowel movement occasionally for several days does no harm. Constipation may often be relieved by paying more attention to one's diet. An increase in the consumption of leafy vegetables, prunes, figs, and whole-grain cereals will help to eliminate constipation. If one feels sluggish, relief may be obtained by drinking several glasses of warm water upon arising each morning, and taking some mild form of exercise before breakfast. If additional laxative effect is desired, half a teaspoonful of salt or the juice of half a lemon may be added to a glass of water. Plenty of outdoor exercise and a regular normal diet followed by eight hours of sound sleep are one's best assurance of normal body functioning.

EXERCISES

1. What is the difference between a laxative, a cathartic, and a purgative?

2. What dangers are connected with the use of laxatives?

3. What causes constipation?

4. When may a person be said to be constipated?

5. Give the chemical composition and give examples of each of the five types of laxatives; tell how each type acts in the body.

6. Which kinds of laxatives are best to use? Why?

7. How may constipation be corrected?

Headache Remedies and Other Pain-Relievers

What causes headaches? A headache is a warning that all is not well within the body. When a headache occurs, the wise person will attempt to discover the cause and adjust his habits so that it will not recur. Just to take some remedy to alleviate the pain is not enough. An occasional headache need not cause alarm, but one which is chronic usually indicates a condition which demands the attention of a physician.

There are many reasons why people have headaches. Certain foods may cause some people to have headaches, seemingly without any other ill effects. Such people have a peculiar make-up which renders them sensitive to the chemicals present in certain foods. This condition may result in a rash, nervous twitchings, or a headache. Such a person has an allergy to these foods. Constipation may cause headaches. Eyestrain is a common cause of headaches and should certainly be given immediate attention, before real damage is done. Overfatigue, working in crowded rooms, poor ventilation, lack of sleep, nervous strain, undue excitement, and worry often produce headaches. An irregularity in the glandular secretions may cause headaches. Impaired functioning of the stomach, liver, kidneys, gall bladder, and other vital organs of the body may result in headaches.

The pain of a headache is generally temporary and will pass away with sufficient rest, sleep, and the resumption of normal living. However, there are times when immediate relief is desirable, and at such times safe sedatives are available to relieve the condition.

What are some common pain-relievers, and what precautions should be observed in their use? Headache remedies are chemicals which have a depressant effect upon the nerves and the nerve centers of the body. The use of any painkiller is risky except under the advice of a doctor. However, there is hardly a medicine cabinet in the land that does not contain some form of headache remedy, and certain information regarding the effect of such remedies should be kept in mind. It is very easy to fall into the habit of taking some such remedy when there is any slight pain. *Aspirin* is the great American painkiller. It is perhaps the safest to take for the relief of pain. Chemically, it is an acetic acid ester of salicylic acid obtained from a coal tar. It is usually sold in five-grain tablets. Even aspirin is not entirely safe, as there are individuals who are sensitive, or allergic, to this drug, and in such cases serious consequences may result if it is taken.

It is extremely unwise to buy a pain remedy of unknown composition, as it may contain a harmful drug. Some pain remedies on the market contain such drugs as derivatives of barbituric acid, acetanilide, "Antipyrine," phenacetin, triple bromides, aminopyrine, and caffeine. Some countries and some states of the United States prohibit the sale of such sleep-producing and pain-relieving remedies without a doctor's prescription. This certainly indicates their danger. All these drugs have a bad effect on the body, particularly the heart. When taken over a long period of time, they become habit-forming. Be sure to look on the label to see if such drugs are listed.

EXERCISES

1. What is a headache an indication of?

2. What are the causes of headaches?

3. How may a headache be cured?

4. How do pain-relievers act to stop a headache or other pain?

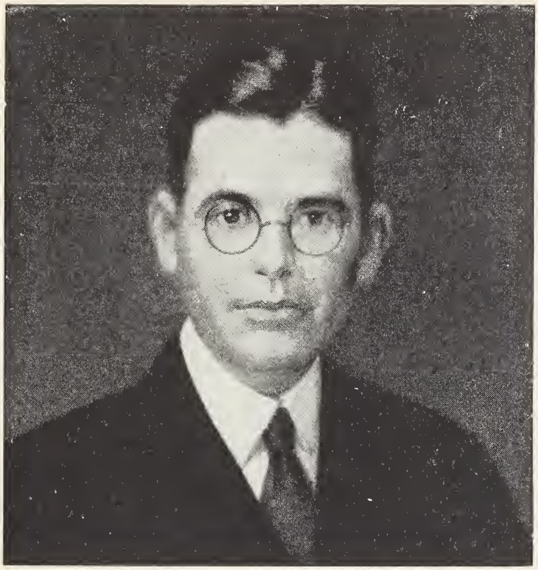
5. Discuss the use of aspirin as a pain-reliever?

6. What are some harmful chemicals which are used as pain-relievers?

7. How can you tell if a product that you buy to relieve a headache has harmful chemicals in it?

Burn Preparations

What are the types of burns? Burns may be caused by fire, hot objects, chemicals, the sun, and hot liquids. Burns from these sources vary in degree of seriousness. *The American Red Cross First Aid Textbook* classifies burns according to the depth to which the tissues of the body are injured. First-degree burns are those in which the skin is reddened;



Dr. Edward C. Davidson, who discovered the effectiveness of tannic acid in the treatment of burns. (From a portrait by J. Raeburn Middleton)

second-degree burns are those in which the skin is blistered; and third-degree burns are those in which tissues beneath the skin are destroyed, sometimes being cooked or charred.

How should burns caused by fire, hot objects, and hot liquids be treated? Burns are usually very painful and sometimes serious. Burns which cover half of the body are usually fatal. If a burn is small, the service of a physician may not be necessary. Immediate relief may be had by submerging the burn in cold water. If a blister forms, the best and safest course is to leave it alone, since opening it increases the possibility of infection. A paste made of cold water and baking soda is soothing to a small burn. The afflicted area should be covered and kept moist as long as the burn is painful.

For the most effective relief, a wet dressing made by moistening sterile gauze with a freshly prepared solution of tannic acid may be used to cover the burned area. Every medicine cabinet should contain a small box (capacity about 2 ounces) of powdered tannic acid. Since the tannic acid solution must be fresh, it should be prepared as needed. Five teaspoonfuls of the dry powder in a glass of water which has previously been boiled makes a solution of proper strength. If no tannic acid is available, a very strong solution of tea, which contains tannic acid, may be used. Picric acid gauze, which may be purchased, also makes a good dressing.

Salves and ointments are common in the medicine cabinet. Those which contain tannic acid are generally good. "Vaseline" and zinc oxide will be found to be soothing. Oils and greases, such as lard, butter, sweet oil, mineral oil, and carron oil, will give some temporary relief. In case of a second-degree or third-degree burn, which usually requires the services of a physician, a salve should not be applied to the burn, because the treatment used by the physician generally necessitates the removal of a salve. Iodine should never be used on a burn. Sterile gauze may be used to cover the burn if it is put on lightly. Cotton should never be used, since its removal is difficult and painful.

How are chemical burns treated? The most frequent of the chemical burns are those produced by acids or alkalies. These burns may be very serious, particularly those of HNO_3 and H_2SO_4. In the chemical laboratory any number of acids, either dilute or concentrated, may be spilled on the body or clothing. The first thing to do in an emergency is at once to place the affected area under a stream of running water. If an acid is causing the damage, the area may, in addition, be soaked in dilute ammonium hydroxide, or a paste may be applied made by mixing water with sodium bicarbonate. Calcium hydroxide solution or limewater may be safely used. If the accident occurs in the home, the same procedure as that described above may be followed. Both ammonium hydroxide (household ammonia) and sodium bicarbonate (baking soda) are commonly found in the home. In addition, milk of magnesia, which you may have in the medicine cabinet, may be used in an emergency. In case an acid gets in the eye, wash the eye with a copious amount of water and then with a very weak solution of baking soda in water. A baking soda solution may be drunk if the acid burn is internal.

Alkali burns include those produced by caustic soda, or lye ($NaOH$), caustic potash (KOH), lime ($Ca(OH)_2$), and concentrated ammonium hydroxide (NH_4OH). Of these, lye burns are the most common. If the alkali is taken internally, the victim should first be made to drink a quantity of some dilute acid solution, such as vinegar diluted with an equal amount of water or fruit juice. A doctor should be called immediately. If the burn is external, the afflicted area should immediately be held under running water and washed thoroughly. The area may then be well soaked with some very weak acid, such as dilute acetic acid or vinegar. Saturated boric acid may also be used, especially in or near the eyes.

After all acid or alkali has been neutralized, the wound may be treated with liquid petrolatum or vaseline or with a tannic acid solution especially prepared for the treatment of burns. In general, the treatment is the same as that for other types of burns.

How may sunburn be treated? Sunburn should be treated like any other burn. It is usually a first-degree burn, though lengthy exposure may cause a second-degree burn. Tannic acid solution is perhaps the best dressing to use on sunburn. Care should be taken not to expose the skin to the sun too long, especially when bathing.

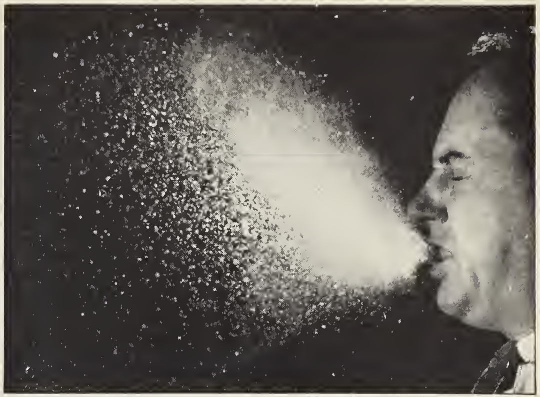
EXERCISES

1. Name and describe the types of burns.
2. How should burns caused by fire, hot objects, and hot liquids be treated?
3. Discuss the value of the various products used in the treatment of burns.
4. Which are the best substances to use in treating burns?
5. What chemicals used in the laboratory will burn the flesh?
6. Describe fully how chemical burns should be treated.
7. How should sunburn be treated?

Cold and Cough Remedies

What causes the common cold? The cold is the most common and the most neglected of all diseases. It is believed to be caused by germ infection, although no cold germ has been isolated. It is also believed that there are a number of different kinds of cold germs and that those of like kind may vary greatly in potency.

Modern life, with its crowded subways, streetcars, busses, motion-picture theaters, crowded apartment houses, stores, and offices, often poorly ventilated, is made to order for the transmission of cold germs. The constant coughing, spitting, sneezing, and breathing in such places of people having colds keep the air contaminated. The handling of money, doorknobs, pencils, handrailings, telephones, dishes, and other objects handled by people with colds aids in the spread of the disease. The failure of people with the disease to take it seriously and to be thoughtful of the health of others also aids in its spread.



Massachusetts Institute of Technology

This actual photograph of a man sneezing, taken by high-speed photography, shows the thousands of droplets of moisture which are expelled into the air with a sneeze. It shows the necessity of covering the mouth during a sneeze. Do you always observe this courteous and healthful practice?

It has been thought, for generations, that climatic conditions, changes in the weather, sudden exposure to the elements, and fatigue are the causes of colds. Though these factors are not the direct causes of colds, we have reason to believe that they may contribute to the contraction of colds. Certainly a body which is overworked, undernourished, and ill-clad has not the resistance to withstand cold germs that a normal, healthy body has.

If it is true that colds are caused by germs, every person who lives a normal life today has many opportunities to come in contact with many cold germs. Some of these cold germs are virulent, and others are weak, just as some animals of the same species are strong, and others are weak. If a person is physically fit, there is a great deal of resistance to the infecting organisms; if a person is in poor condition and run down, his resistance is weak. Colds may affect persons differently. They may occur as head colds, throat colds, or colds of the lungs.

Is it possible to cure a cold? This question is asked thousands of times by the victims of colds. This, in itself, indicates that there is no cure effective for everyone. What proves effective for one person may not benefit another. Indeed, the same remedy may prove ineffective the second time that it is used by the same person. One authority recently said that it takes a week to cure a cold under the care of a physician, whereas it takes seven days to cure one without his aid. This is probably exaggerated, but it does indicate that little is known about colds.

One is led to believe by the numerous newspaper advertisements and radio programs that all one has to do to get rid of a cold is to drink a foaming liquid, swallow a sugar-coated pill, eat a certain kind of food, drink plenty of orange juice, or sit under a sun lamp. Many persons try these remedies and, after several days, get well; they probably would have anyway.

Much research has been devoted to the problem of cold remedies. However, medical science has been unable to find a specific for colds. There are many products and patent medicines sold as cures for colds and coughs. Scientific experimentation proves that the claims made for such products are often highly exaggerated. You may be interested in knowing the composition of some of these products.

Cold tablets and powders. These preparations usually contain a pain-reliever, such as acetanilide or aspirin, an alkalizing agent such as sodium bicarbonate, and a laxative, such as phenolphthalein. A few of them also contain substances such as quinine or vitamins. While some of these ingredients may be prescribed by a doctor for colds in individual cases, this does not mean that a standard product containing these ingredients is valuable for everyone who has a cold. For this reason, to rely on cold tablets or powders to cure a cold is a very questionable practice.

Sprays, nose drops, and inhalants. These preparations usually contain such a chemical as menthol, ephedrine, camphor, thymol, or "Benzedrine" dissolved in liquid petrolatum. These substances have either a stimulating or a constricting effect on the mucous membrane and thus afford some temporary relief in a congested cold condition. Their use as curatives is questioned by physicians. Moreover, there is some danger in their continued use, because some of the oil may be drawn into the lungs, causing inflammation and even pneumonia. There is also some danger that the oil may clog the openings into the sinuses, causing increased infection.

Ointments and salves. These preparations contain many of the same chemicals as are found in nose drops and sprays except that the ingredients are mixed with heavy, semisolid petrolatum. They are usually applied on the chest or throat, the area then being covered with a warm flannel, or other woolen cloth. The warmth causes the vaporization of the volatile materials and also causes dilation of the blood vessels, thus relieving the congestion. The chief value of these preparations lies in the heat applied. Probably the best source of heat in such a case is the old-fashioned mustard plaster.

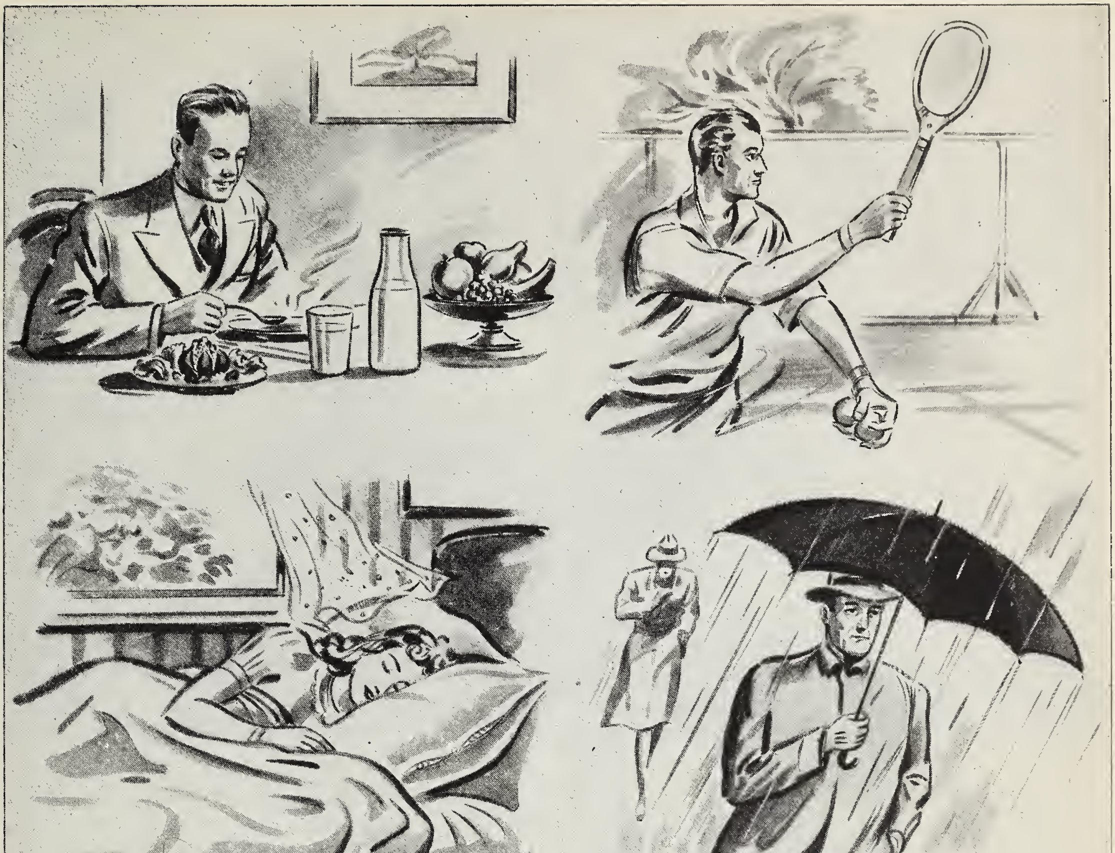
Gargles. There are a number of these preparations on the market which purport to be a relief for colds. They usually contain thymol, eucalyptus oil, menthol, and zinc chloride dissolved in alcohol and water. A flavoring agent, such as oil of wintergreen, peppermint, or cinnamon, is added to make the solution more palatable. Sometimes a coloring agent, such as burnt sugar, is also added. These preparations are said to kill the germs of the throat and mouth, but experimental evidence proves that they are of little value for this purpose.

Cough drops. Cough drops have no effect upon a cold, though they may afford relief from a tickling cough. Perhaps candy drops, such as cherry or lemon drops, are just as effective in relieving the dryness of the throat and lessening the tickling sensation.

The care of a cold. Most doctors will advise patients with colds to go to bed and rest. This is undoubtedly the most valuable advice that can be given. Rest and sleep will help to build up the resistance of the body for combating the disease effectively. In addition, isolation protects people with whom one would otherwise come in contact.

If the patient is constipated, a mild laxative may be administered to remove undigested food from the intestines.

If a cold is accompanied by a fever, a sponge bath with warm water may give relief. The bath should be followed by a brisk rub with a towel. During fever there is an excess destruction of tissue; hence a nourishing diet is advisable to provide plenty of food for the body.



How do these practices help to prevent catching the common cold?

Ewing Calloway

The patent-medicine man, dispenser of expensive and worthless cure-alls, is gradually disappearing. This is an unscientific method of treating disease. In the next picture we see the scientific method of treating disease. The doctor is making a thorough diagnosis of the disease by examining the patient

A body with fever perspires freely, and therefore the body needs a good deal of water. Consequently water should be drunk in quantities. Hot lemonade and orangeade are valuable principally because, in drinking them, the patient gets a good deal of water. Some doctors are now experimenting with the use of vitamin C, and others are using sulfa drugs in the treatment of the common cold. However, the use of these substances is still in the experimental stage, and they should be taken only on the advice of a physician. Some physicians advise patients to take about 10 grains, or $\frac{1}{4}$ teaspoonful, of bicarbonate of soda in a glass of water after meals.

Aspirin is often taken to lower the fever and reduce the pain. It has already been pointed out, however, that for some people aspirin may be inadvisable.

EXERCISES

1. What causes a cold?

2. What are the usual constituents of cold tablets and powders? Of what value are they?

3. What ingredients are found in sprays, nose drops, and inhalants? What dangers are connected with their use?

4. What materials are present in cold ointments and salves? Of what value are they?

5. Do gargles kill germs in the mouth and throat, as stated in many advertisements? Why or why not?

6. Of what value are cough drops?

7. How should a cold be cared for?

Anesthetics, Narcotics, and Hypnotics

Anesthetics. The value of anesthetics to mankind cannot be overestimated. Before anesthetics or other sedatives were used, the operating rooms of hospitals were ghastly places where hideous screams and groans of the patients were the rule rather than the exception. This atmosphere made it impossible for the surgeon to do calm thinking, and the operations were frequently very hurriedly and inaccurately done. Anesthetics have made it possible for biochemists to use lower animals in the study of diseases and methods of surgery. From such experimentation has sprung most of our knowledge about the living processes in relation to health and disease. Moreover, anesthetics have been of direct value in the saving of lives when operations become necessary.

Contrary to what one might think, this great boon to mankind, anesthetics, has been used for only a hundred years. Dr. Crawford Long of Jefferson, Georgia, used ether on a patient for whom he was removing a tumor in the year 1842. This was the first time that a practicing physician had dared to put a patient to sleep with a chemical substance before operating. This use of an anesthetic was successful, and, two years later, Dr. William T. G. Morton gave a public demonstration in the Massachusetts General Hospital of a leg amputation where the patient was made to inhale ether fumes. This too was a successful operation, and, before many years, ether was gradually put to use as an anesthetic in hospitals in the United States. However, the general application of this important discovery for the use of all people and all practitioners came slowly, a condition which is true of most scientific discoveries. And it was probably from twenty-five to thirty years before the use of anesthetics became very general. Descriptions of the treatment of the wounded soldiers during the Civil War do not indicate much knowledge of anesthesia at that time.

Anesthetics belong to a type of medicines or drugs known as sedatives. A sedative is a chemical substance which tends to dull the senses. In addition to anesthetics, there are several other kinds of sedatives, among which are substances known as narcotics and hypnotics. You will want to know the chemistry of each of these three kinds of drugs. Therefore they will be described separately.

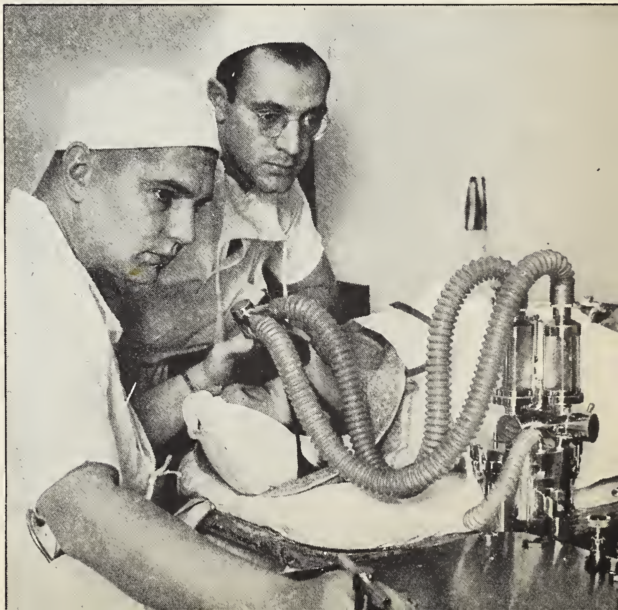
What are anesthetics? If we study analytically the substances which have a sedative effect upon the body, we find that this action is due to the kinds of molecules or parts of molecules in these drugs. For example, chemists have discovered that substances which have been found to contain the C_2H_5 group of atoms have such an effect. This group of atoms, you will recall, is known as the ethyl group. Ether contains this group, as is shown by the formula $(C_2H_5)_2O$, or, as it is sometimes written, $C_2H_5 \cdot O \cdot C_2H_5$. Its chemical name is diethyl oxide. Ethyl alcohol (C_2H_5OH) also contains this group of atoms and, of course, is a sedative. Other substances which produce this same kind of sedative action are ethylene (C_2H_4), chloroform ($CHCl_3$), acetylene (C_2H_2), and nitrous oxide (N_2O). The substances which produce narcotic and hypnotic sedative action also have a characteristic chemical structure.

The action of general anesthetics within the body. The action of any anesthetic within the body is due to two factors: its physical property of solubility in fats and water and its chemical characteristic of combining with nerve tissue.

It is obvious that for any drug to act upon the body, it must first dissolve in the fluids of the body. Since the sedative action of a drug results from its effect on the nerves, it is also obvious that the drug must dissolve in the fatty and watery substances which surround the nerves. All the anesthetics mentioned above will dissolve in fat readily and some are soluble in water. In addition, they have

An anesthetic being administered to a patient in a modern hospital. Contrast this method of producing anesthesia with methods of a century or more ago

Ewing Galloway



Bettman Archive

The first public demonstration of the use of ether as an anesthetic was made at the Massachusetts General Hospital, October 16, 1846, by Dr. W. T. G. Morton

the chemical property of combining with the nerve tissue, thus destroying temporarily its ability to receive stimuli. When one is under the influence of an anesthetic, one's body is, therefore, temporarily insensitive to pain; that is, the body does not have feeling, and no messages are transmitted to the brain by the nerves.

An anesthetic must be volatile if it is to be administered through the respiratory tract. All those mentioned here are, at ordinary temperatures, either easily vaporized liquids or gases. There are some anesthetics which can be administered through the rectum or injected into the spine. These do not have to be volatile, but they must have properties which enable the body fluids to assimilate them.

The anesthetic action or sedative action of an anesthetic is exerted faster than the body can rebuild the fatty substances surrounding the nerves. An expert doctor or anesthetist knows exactly how much of the anesthetic the human body can stand, and very careful control is exercised whenever an anesthetic is given, so that the patient is not harmed by the destruction of too much fatty and nerve tissue.

After the anesthesized person ceases to breathe the fumes, the body soon begins to throw off the poison. The fatty tissue is rebuilt, the person becomes conscious, and is, of course, again sensitive to pain.

The making of ether and other anesthetics. Ether is made by distilling ethyl alcohol and partially concentrated sulfuric acid together, as shown by the following equation:

$$2\,C_2H_5OH + H_2SO_4 + \text{heat} \longrightarrow (C_2H_5)_2O + H_2SO_4 + H_2O$$

This equation may be written graphically as follows:

$$\begin{matrix}C_2H_5O\\C_2H_5\end{matrix}\boxed{\begin{matrix}H\\OH\end{matrix} + H_2SO_4} \longrightarrow \begin{matrix}C_2H_5\\C_2H_5\end{matrix}\!\!>\!O + H_2SO_4 + H_2O$$

The concentrated sulfuric acid is a dehydrating agent, and therefore the chemical action continues as long as there is a sufficient number of H_2SO_4 molecules to take up the water molecules given off by the two molecules of ethyl alcohol.

Ethylene can be made in the same manner and by using the same materials, with the exception that the sulfuric acid must be more concentrated. This more highly concentrated sulfuric acid removes another molecule of H_2O from the two molecules of ethyl alcohol and leaves two molecules of C_2H_4. This can be shown by the equation

$$\begin{matrix}C_2H_4\\C_2H_4\end{matrix}\boxed{\begin{matrix}HOH\\HOH\end{matrix} + \text{conc.}\,H_2SO_4} + \text{heat} \longrightarrow 2\,C_2H_4\uparrow + H_2SO_4 + 2\,H_2O$$

In each case, the ether or the ethylene is distilled off and condensed. The reaction must be carefully controlled in order to ensure an absolutely pure product. Purity is important in an anesthetic.

Nitrous oxide is made by decomposing ammonium nitrate, as shown by the equation

$$NH_4NO_3 + \text{heat} \longrightarrow N_2O\uparrow + 2\,H_2O$$

Chloroform is manufactured by the reaction of chloride of lime upon acetone or alcohol.

Acetylene is made by the action of water upon calcium carbide, as follows:

$$CaC_2 + 2\,H_2O \longrightarrow C_2H_2\uparrow + Ca(OH)_2$$

Acetylene is sold as "Narcylen," but is not widely used as an anesthetic.

The best anesthetic. Your doctor or surgeon is much better prepared to choose an anesthetic than anyone else, and his advice should be followed without question. However, it is interesting to know of the varying physiological effects of the different anesthetics.

The inhalation of ether and air in sufficient amounts to produce anesthesia causes the patient to be unconscious for from two to four hours after an operation. The patient is usually nauseated for a considerable time after an operation. There is some danger of a patient's contracting pneumonia after the use of ether as an anesthetic, owing to its irritant effect on living tissue. However, ether is still widely used because the anesthesia it produces is one of deep relaxation.

Chloroform is a very quick, powerful anesthetic, but occasionally its use may be fatal because of destructive changes in the liver and other organs. This action generally occurs several days after the operation and is unpredictable. Chloroform is not often used as an anesthetic because of the danger of chloroform poisoning.

A mixture of ethylene and oxygen is replacing the use of ether in many hospitals. Its action is quick. The patient loses consciousness and goes to sleep with only a few breaths of the anesthetic and is completely relaxed. Furthermore, he will regain consciousness within from three to ten minutes after the mask is removed. There is less nausea than with ether.

Nitrous oxide, or "laughing gas," is also mixed with oxygen in its modern use as an anesthetic. It produces a very short anesthesia and one generally free from any postoperative nausea. Since the unconscious period is short (1 to 3 minutes), its use must be restricted to an operation requiring little time, such as some operations in dentistry.

No one can even guess the misery and suffering which men have been spared by the discovery and use of anesthetics. The pain of operations has been relegated to the past. Many lives have been saved and torture has been eliminated from surgery by the use of anesthetics.

What are narcotics? *Narcotics* is a word applied to those drugs which are sedative in their action upon the body but which also are analgesic, that is, produce insensibility to pain. Some are used by physicians to render restricted areas of the body insensitive to pain (local anesthesia), while others are used to relieve pain and induce sleep. Narcotics are, as a rule, habit-forming and, therefore, should be taken only on a doctor's advice.

The opiates, such as morphine, "Heroin," codeine, laudanum, opium, and cocaine and its derivatives, are the drugs most commonly thought of as narcotics. Marijuana is another common narcotic.

Ewing Galloway

Nitrous oxide, or "laughing gas," is often administered in minor operations, such as some operations in dentistry

Alkaloids. There are many different drugs contained in crude opium. They are known to chemists as alkaloids because they are mildly basic substances. Most alkaloids are derived from the seeds of certain plants. Opium is obtained from the seeds of a species of Oriental poppy. If crude opium is treated with the proper chemicals, the other narcotic alkaloids, such as morphine, codeine, "Heroin," narcotine, papaverine, and thebaine, may be separated from it. Laudanum is made by dissolving opium in grain alcohol. Marijuana is obtained from Indian hemp, which grows profusely in most temperate climates. The drug in marijuana is called hashish or bhang. All these narcotics are known to be dangerous intoxicants when used habitually.

They are all very habit-forming, and even a single dose of any one of them may enslave a person to its use.

The effect of narcotics on the body. Narcotic drugs are said to be intoxicants because of their action on the body. The action of all narcotics is similar, whether they are taken by tablet, by hypodermic injection, or by inhaling the smoke of cigarettes which contain them. The first physiological effect of a narcotic is one of exhilaration and well-being; and, if enough is taken, there is freedom from pain. After these effects wear off, they are followed by depression and eventually sleep. However, a person who has become addicted to the drug finds it difficult to sleep soundly and generally can only sink into the abyss of nightmare. Narcotics, especially morphine, are useful in the hands of a competent physician in alleviating pain. But they become man's worst enemy in the hands of the ordinary person. Morphine, marijuana, or any other of these alkaloids becomes more essential to the addict than bread or water. He thinks only of ways to get more of the drug to which he has become habituated. He is never normal in his actions with people, and, in some stages of drug intoxication, he is potentially a dangerous criminal.

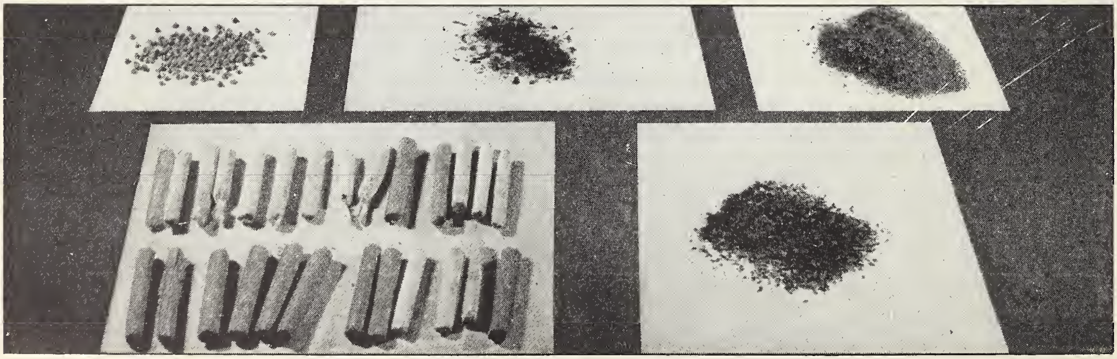
The narcotic traffic. Fortunately, the United States has placed severe restrictions on the sale of narcotic drugs, and the use of these drugs is carefully supervised. However, there are some unscrupulous persons (generally addicts themselves) who attempt to sell the various narcotic drugs illegally. There is constant danger from such sources, and government officials are always on the lookout for "dope" peddlers. The most recent narcotic drug to be widely sold illegally is marijuana in the form of cigarettes. These cigarettes are sometimes offered free to high-school and college boys and girls just to get them started in the habit. This is a heinous practice, and, wherever noticed, it should be reported to the authorities at once. Court records show that many juvenile criminals are boys and girls who have become addicted to marijuana-cigarette smoking. The moral and physical degeneracy which always follows the habitual use of narcotic drugs is so definitely proved that everyone should attempt to stamp out the "dope" traffic whenever he has an opportunity to do so.

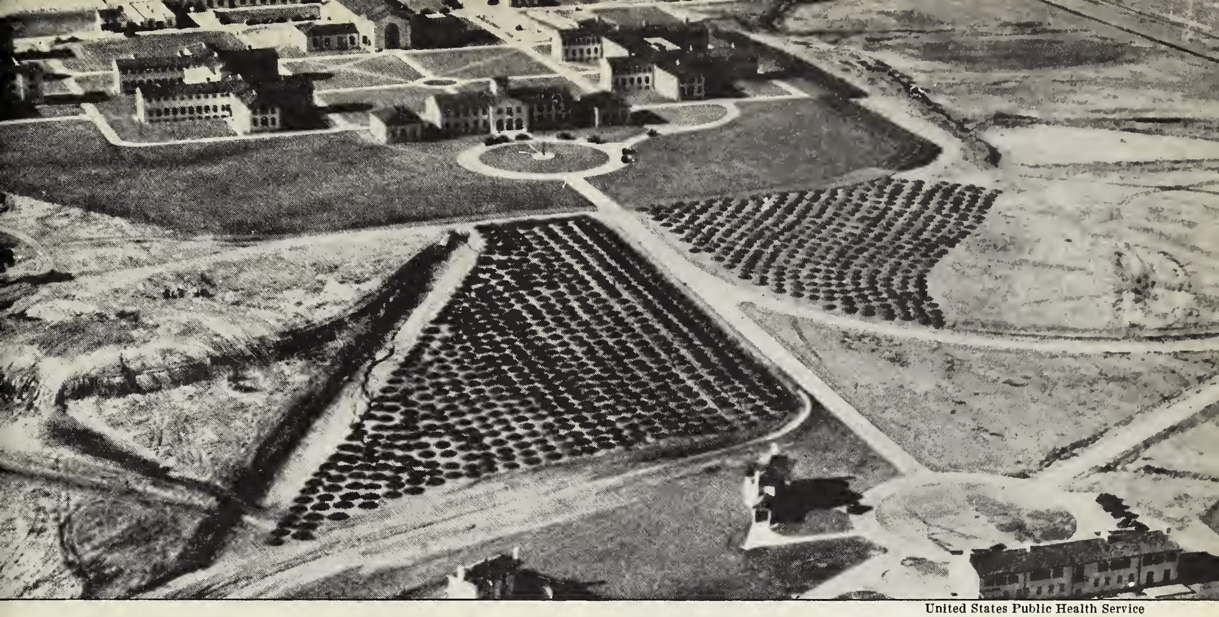
Local anesthetics—gifts of chemists. Modern synthetic chemistry has given us many new narcotics which have become essential in the relieving of pain but which are non-habit-forming. Modern local anesthetics are mainly derivatives of the drug cocaine. Local anesthetics have played almost as important a role in the elimination of suffering as general anesthetics. Local anesthetics, when they can be used, as in many minor operations, are generally preferred to general anesthetics because they do not cause the shock and nausea which commonly accompany the use of general anesthetics. In addition, local anesthetics are used for major operations when a patient's condition is such as to render a general anesthetic dangerous.

The use of local anesthetics. Local anesthesia may be brought about in one of three ways. Most often a water solution is injected under the skin of

Marijuana cigarettes. What drug is present in these cigarettes?

United States Public Health Service





United States Public Health Service

The newer of the two United States Public Health Service hospitals for the treatment of narcotic addicts, at Fort Worth, Texas. A unique feature of this hospital is that it bears no resemblance to a prison, although narcotic addicts must be closely watched to prevent escape. A similar hospital is located at Lexington, Kentucky

the area to be operated on. Thus the nerves which end in this region are temporarily paralyzed, and the patient is unable to feel any pain in that area. Second, the hypodermic needle is also used to inject the narcotic directly into the nerve trunk which serves a certain portion of the body, thus anesthetizing that region. Dentists use this method in "blocking" a main nerve before extracting or filling a tooth. Third, the narcotic, either in solution form or in solid form, may be applied directly to the skin which is to be made insensitive to pain.

History of local anesthetics. Local anesthetics have not been in use as long as general anesthetics. Dr. Koller of Vienna is given credit for their first effective use in 1884. However, the Spanish explorers of South America really discovered cocaine. They noticed that the Indian runners of Peru chewed the leaves of a certain coca plant when they had to make steep mountain climbs. By chewing these leaves, the Indians became less sensitive to hunger and fatigue. This plant was taken to Europe and cultivated, but its use led to disastrous drug habits. The world had to await the experiments of Dr. Koller before it could avail itself of the surgical benefits of cocaine. But almost as soon as it was heralded as an invaluable aid to surgery, the discovery was made that cocaine was poisonous, and that occasionally its use led to the death of the patient. Its practical use awaited the development of less harmful derivatives. Chemists found that by substituting and eliminating certain groups of atoms in the molecule of cocaine, a much less toxic and more efficient local anesthetic could be produced. The name of this synthetic narcotic which resembles cocaine, but which is far better, is "Novocain." "Novocain" was introduced in 1905 and has been universally used ever since. "Novocain" is not habit-forming, as cocaine itself is.

Another product of analytical experimentation with cocaine molecules, which is similar to "Novocain," or procaine as it is sometimes called, is "Butyn." It was given to the world about 1920. It is much more effective than procaine when brushed over an area or instilled into an area such as the eye. Also, it acts more promptly than procaine, but it is more toxic. It is non-habit-forming.

A drug used by many surgeons at the same time that a local anesthetic is injected is epinephrine, or adrenalin. Biochemists discovered this substance and isolated it from the suprarenal glands of animals. It is a helpful supplemental agent because its injec-

Ewing Galloway

A local anesthetic is often administered to a patient where the operation is a minor one

tion into any area of the body produces a constriction of the blood vessels. This action tends to keep the "Novocain" or other local anesthetic from being diffused to the other parts of the body, and the anesthetized area remains insensitive to pain much longer. This discovery by biochemists, which occurred about 1900, has been of tremendous importance to doctors. Epinephrine, or adrenalin, is an ideal drug for the purpose because it is one of the body's own drugs. The future of local anesthetics lies in our finding other local anesthetics with this characteristic.

What are hypnotics? A hypnotic is a sedative drug which tends to produce sleep when it is taken by mouth or injected into the body. It has no anesthetic action. Insomnia, or sleeplessness, is a definite condition of ill health and is frequently a common ailment. One of the necessary requirements for healthful living is sound, restful sleep. The worst feature of insomnia is the vicious cycle which it promotes: the less sleep, the more sleeplessness. Therefore insomnia is a condition which needs the attention of a physician. Fortunately, the chemist and the doctor have produced some excellent hypnotic drugs which are specifics against insomnia, just as quinine is a specific against malaria. These substances have been found to produce normal sleep, and they are not habit-forming if they are rightly used under the direction of a physician.

The chemical nature of a hypnotic. Chemists have discovered that there are several different kinds and groups of atoms that tend to produce sleep. For example, it has long been known that the bromide ion (Br^-) of bromide salts has a stupefying or quieting effect on the nerves. Sodium bromide ($NaBr$) and potassium bromide (KBr) are typical salts used by physicians to bring about this result. The ethyl group of atoms (C_2H_5) has already been explained as a constituent of many kinds of molecules which have a sedative action upon the body. The commonest drug which contains this group is ethyl, or grain, alcohol (C_2H_5OH). However, its use is so habit-forming that few doctors ever prescribe it as a hypnotic. You will learn more about this material and its harmful effects on the body later.

Urea as a source of hypnotics. The one material which has yielded more hypnotic substances than any other when subjected to the magic touch of the synthetic chemist has been urea ($(NH_2)_2CO$, or $H_2N \cdot CO \cdot NH_2$). Urea is a natural waste material formed in the body when certain protein substances are burned, and is excreted in the urine. Urea itself has only mild sedative action, but some of its derivatives are excellent hypnotics. Many dozens of such derivatives have been created by the synthetic organic chemist. However, only a few have been found by actual trial to be nontoxic, useful, and valuable hypnotics. These derivatives contain the ethyl group and the urea molecule, and some also contain the bromide ion.

There are two urea derivatives commonly used by doctors, barbital and phenobarbital. Both are produced by the artistic touch of the experimental chemist. Both are safe and efficient. Barbital is most often used to promote a deep restful sleep after operations. It is also known as "Veronal" and was discovered by the great German chemist Fischer in 1903.

Phenobarbital is similar to barbital chemically, but it has a slightly different physiological action. It is a specific for insomnia, but it also tends to act specifically upon the motor area of the brain. This latter action makes it useful in the treatment and control of nervous diseases which affect muscular action. It is widely used to prevent and make less severe epileptic seizures and St. Vitus's dance.

A word of caution. Hypnotics, such as those just described, are to be found in many patent medicines and in some states can even be purchased without a doctor's prescription. This condition is an extremely dangerous one, as these drugs, although valuable, should be used only as prescribed by a doctor. Their prolonged use by a person is habit-forming, and may result in a poisonous accumulation in the body. These drugs have an important use as relievers of insomnia, but this use is not one that can be left to the judgment of the ordinary person. You should never attempt to prescribe them for yourself. After all, the best sleep-producer is good food and plenty of outdoor exercise. If you are troubled with insomnia, do not worry about it; but if it persists, consult a competent doctor.

EXERCISES

1. Compare the surgery of a hundred years ago with that of today.

2. Who discovered the use of ether as an anesthetic?

3. What is a sedative?

4. From a chemical viewpoint, what is an anesthetic?

5. What causes anesthetics to have a sedative effect? Explain fully.

6. How are anesthetics administered?

7. How are the following anesthetics prepared: (*a*) ether; (*b*) ethylene; (*c*) nitrous oxide; (*d*) chloroform? Write equations for the first three reactions.

8. Discuss the uses of each anesthetic in Exercise 7 and state the advantages and disadvantages of each.

9. What are narcotics?

10. Name several commonly used narcotics.

11. What are alkaloids?

12. What alkaloids are obtained from opium?

13. What is marijuana?

14. How do narcotics affect the body? Explain fully.

15. How do "dope" peddlers operate?

16. What is meant by "local anesthesia"?

17. How were local anesthetics discovered?

18. Name some of the more common local anesthetics and give their specific uses.

United States Public Health Service

During rehabilitation certain selected patients in the United States Public Health Service hospitals are given technical training in laboratory diagnostic procedures, such as gastric analysis and making blood counts. The development of good industrial habits and special training for jobs to be held after discharge are considered valuable in aiding patients to readjust themselves to society without resorting again to the use of drugs

19. What are hypnotics?

20. What is the chemical nature of hypnotics?

21. What hypnotics are obtained from urea?

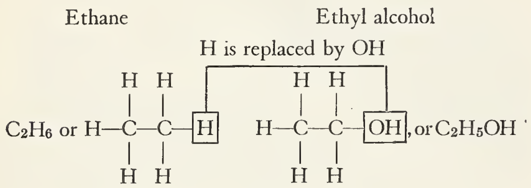
22. What dangers are connected with the use of hypnotics?

Stimulants

Alcohol. The use of alcohol has long been a subject of discussion. The information available about alcohol is very often colored by emotional statements rather than statements of scientific fact. There is a great need today for information, backed by scientific experimentation, about the effect of alcohol. If you have read very much about the use of alcohol, you have undoubtedly been confronted with contradictory statements from which you are supposed to draw conclusions.

In this discussion of alcohol, an attempt will be made to present scientific facts rather than information colored by the emotions. Where scientific facts are not available, both sides of the question will be presented.

What is alcohol? In Unit 12 a short discussion of the chemical nature of alcohol was presented. You will recall that there are many alcohols and that they may be described as resulting from the displacement of one or more hydrogen atoms from the compounds of the methane series of hydrocarbons. Thus ethyl alcohol, the alcohol under discussion, can be shown structurally, as it relates to ethane of the methane series, as follows:



Alcohol may also be thought of as being very closely related to the sugar glucose, in that a chemical reaction which eliminates two molecules of carbon dioxide results in the formation of two molecules of ethyl alcohol:

$$C_6H_{12}O_6 \longrightarrow 2\ C_2H_5OH + 2\ CO_2$$

Ethyl alcohol is a colorless, sweet-smelling liquid with a boiling point of 78° C and a specific gravity of .79. It burns with an almost colorless flame and is an excellent solvent. Although it is not a very potent destroyer of germs, it does check their growth. For this reason, it is used widely by physicians and in the home for bathing abrasions of the skin.

How is alcohol made? Grain alcohol can be made by the fermentation of any substance that contains starch or sugar. Grains such as corn, barley, and rye are commonly used. Potatoes and many different fruits are also used. The methods of manufacture vary, but they are all based upon fermentation. The fermentation of starch or sugar occurs only when yeast plants are present. The following reactions show the production of alcohol when yeast acts upon solutions of starch and sugar:

$$\overset{\text{starch}}{(C_6H_{10}O_5)_n} + H_2O + \text{yeast} \longrightarrow \overset{\text{alcohol}}{2\ C_2H_5OH} + 2\ CO_2\uparrow$$

$$\overset{\text{glucose}}{C_6H_{12}O_6} + H_2O + \text{yeast} \longrightarrow \overset{\text{alcohol}}{2\ C_2H_5OH} + 2\ CO_2\uparrow + H_2O$$

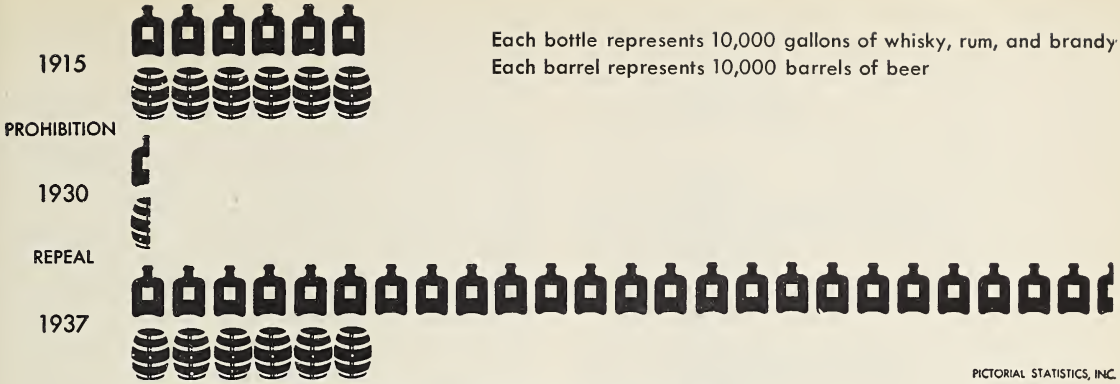
Alcoholic beverages may be roughly divided into three classes: malt liquors, such as beer and ale; fermented liquors, such as wine and cider; and distilled liquors, such as whisky, brandy, and gin.

Beer is made from malt, which is made from barley or other grains. The barley is allowed to germinate and, in so doing, produces an enzyme called diastase. When the maximum amount of the enzyme is produced, the germinated grain is dried, ground, and called malt. It is then mixed with water, and, at a temperature of 150° F to 160° F, the enzyme converts the grain starch into the sugar maltose. Yeast is then added and acts upon the maltose, converting it into alcohol and carbon dioxide. Hops are added to produce a bitter taste, and the mixture is filtered and bottled.

Wines are usually made from grapes. The juice, which contains from 9 per cent to 16 per cent sugar, is pressed from the fruit. Yeast spores are always present in the juice of ripe grapes. The juice is allowed to ferment for from two weeks to a month, during which time the yeast acts upon the sugars to produce alcohol. When the alcoholic content reaches about 12 per cent, the yeast ceases to act. Dry wines are those in which most of the sugar has been acted upon, so that they are not sweet to the taste. Sweet wines contain sugar in solution which has not fermented.

If a solution of fermented grain or malt is distilled, the alcoholic distillate obtained is called whisky. The average whisky is about 100 proof, or 50 per cent alcohol. One bottle (12 ounces) of beer is equivalent in alcoholic content to 6 ounces of wine or 1 ounce of whisky.

Is alcohol a stimulant? In the study of anesthetics you learned of the part played by the ethyl group (C_2H_5) in the production of hypnosis in the body. The hypnotic effect of alcohol is undoubtedly due to the presence of the ethyl group. Although alcohol has been used for this purpose since early



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Liquor production in the United States

times, it has now been replaced in the medical world by better hypnotics.

Whether alcohol is a stimulant or a depressant has long been debated. The debate would be more profitable if some common understanding could be reached in regard to what a stimulant is. Many of those who write about alcohol have definitions of their own of a stimulant. One will say that a stimulant is a substance which increases heart action; another, that it produces an exhilarated feeling; others, that it causes an increase in work efficiency, keener mentality, and so forth. In this discussion our definition of a stimulant will be that it is something which increases activity within the body.

Some authorities believe that alcohol acts as a direct stimulant, just as adrenalin does. That is, it increases the heart action by directly exciting the nerves which control the heart. It has been proved that adrenalin causes this type of reaction.

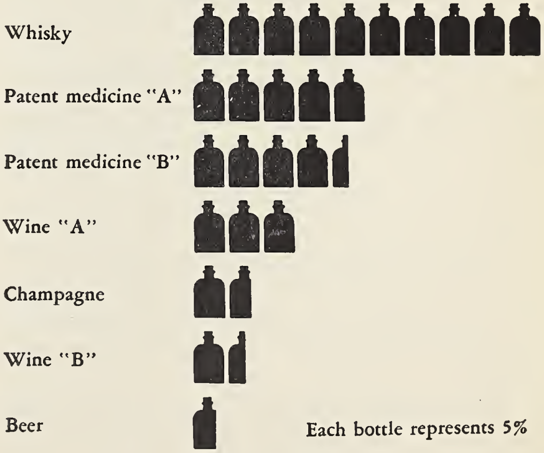
The best scientific evidence indicates that alcohol causes increased heart action in an indirect manner. This is known to be true because alcohol first paralyzes the nerves of the brain which control the heartbeat. Thus the "brakes" which control the heartbeat are released, allowing the heart to beat more rapidly. Thus alcohol is a depressant because it deadens the nerves which control the heart.

How does alcohol affect the body? Alcohol does not require digestion, because it can be absorbed directly into the blood stream. After passing into the blood stream, alcohol, which is a food, burns and supplies the body with energy. However, the amount of alcohol which can be oxidized by the body is limited. If more than this amount is taken into the body, the excess alcohol accumulates in the blood and tissues.

Small quantities of alcohol are manufactured in the body from sugars, but the body seems to be able to use this alcohol without any detrimental effect. The alcohol that is drunk in the form of beverages is generally in excess of the amount that the body is equipped to burn.

It is well known that a given amount of alcohol will not produce the same effect upon all people. However, some general observations based upon experimentation can be made.

Relative percentages of alcohol
in liquors and patent medicines



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[1] From Curtis, Caldwell, and Sherman's *Everyday Biology*, Ginn and Company.

Alcohol acts upon the higher nerve centers and, in so doing, affects a person's intelligence and judgment. The depression of the nerves of the brain causes an increase in the heartbeat, slowing of the peristaltic motion of the stomach, and dilation of the arteries and capillaries.

Alcohol, even in small amounts, will slow up a person's reaction time. This effect is the cause of many automobile accidents. Experiments have been carried on to show that the drinking of alcohol reduces endurance and diminishes physical fitness.

When food is eaten by a person who has drunk alcohol, there is an abnormal flow of saliva and gastric juices. This increase produces more of these juices than are needed for digestion, thus overtaxing the glands which produce these juices. In addition, alcohol has a tendency to draw water from food, which often causes the food to harden, thereby retarding digestion. Therefore large quantities of alcohol delay the emptying of the stomach.

Alcohol, in small amounts, is a food in that it burns in the tissues to produce energy. However, it cannot be stored, as most other energy-producing foods can.

Many who drink alcohol claim that it warms the body. This is a false belief. Alcohol causes the arteries and capillaries of the skin to enlarge, with a corresponding increase in the flow of blood. This increase releases an added amount of heat, which, in turn, produces a false feeling of warmth. In reality, the body is colder, because heat is given off faster than it can be generated.

The person who drinks alcoholic beverages excessively is very apt to lose control of his emotions. Intoxication causes a loss of the feeling of responsibility, which results in a person's doing many things that he would not do under normal conditions. The desire to escape from reality may cause a person to become a habitual user of alcoholic beverages.

Insurance companies have made careful and extensive studies of the effects of alcohol. Their statistics give positive proof that those who abstain from the use of alcohol live longer than those who drink it.

Coffee and tea. The use of coffee and tea has been gradually increasing in the United States. The average annual consumption of coffee is about 13 pounds per person, and that of tea about 1 pound per person. Seven out of ten persons use one or both of these beverages. The drinking of tea or coffee has become habitual with many persons.

The habit-forming properties of these beverages are due mostly to the drug caffeine and partly to the volatile oils found in the coffee berry and the tea leaves. Tea contains about twice as much caffeine by weight as coffee. However, since a smaller amount of tea is used in brewing the beverage, a cup of tea contains about the same amount of caffeine as a cup of coffee—approximately 1 grain. Tea leaves contain 25 per cent tannin, whereas coffee berries contain a very much smaller amount.

Caffeine is a habit-forming drug which acts as a stimulant. Beverages which contain it are probably less harmful than those which contain other habit-forming drugs; nevertheless many undesirable conditions of the body can be traced to their use. The effects of this drug vary with the individual. A person with a calm temperament may experience only a mild feeling of exhilaration from caffeine, while a highly nervous person may be stimulated to intense nervous excitement.

It has been discovered, through actual experimentation, that those who are habitual users of tea or coffee are frequently affected by stomach disturbances, nervousness, dizziness, restlessness, and sleeplessness.

The use of tea and coffee is so common that many persons never think of attributing any of these disorders to the habitual use of these beverages. When confronted with the suggestion that tea or coffee may be causing their insomnia, loss of appetite, or restlessness, they reason that this cannot be true, because they have been using these beverages for years without ill effects. They fail to realize that the body is continually changing and that susceptibility to these drugs may be gradually increasing.

It is now possible to obtain the so-called decaffeinated coffee. This coffee has from 50 per cent to 70 per cent of the caffeine removed. Although this is an advantage, it must not be forgotten that the harmful volatile oils, such as furfural and pyridine, still remain in the brewed coffee.

Coffee substitutes, which are usually made of roasted grains, may be purchased instead of coffee. Many persons who are sensitive to the effects of caffeine use these coffee substitutes.

There are a number of different brands of carbonated beverages on the market which contain caffeine. The caffeine for most of these beverages is obtained from the kola nut. The average-size glass of such a drink contains about half as much caffeine as that found in a cup of coffee.

There are several preparations on the market which guarantee sleeplessness for a long period of time. These preparations contain caffeine as the active ingredient. A special appeal is made by the manufacturers of such preparations to tourists and night drivers. The use of these preparations is definitely detrimental to health.

Tobacco. There has been a tremendous increase in the consumption of tobacco in the United States during the past fifteen years. This change has been due, in part, to an increase in the number of men smokers, but it has also been due to an increase in the number of women smokers.

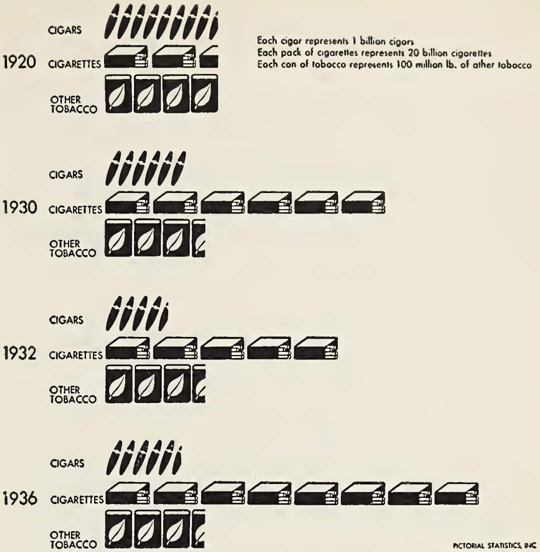
The most harmful drug present in tobacco is an alkaloid called nicotine. The amount of this drug in tobacco varies from 2 per cent to 8 per cent, depending on the kind of tobacco and the location where it is cultivated. Nicotine is a yellowish oily liquid which turns brown on exposure to air. It has an acrid burning taste and is very poisonous. If the nicotine from a cigar were injected into the blood stream of a person, it would be fatal.

Fortunately, when tobacco is smoked, only a small amount of the nicotine is retained by the body. Part of that which is retained is absorbed by the lungs, while another part stays in the mouth to be swallowed with the saliva.

In addition to nicotine, tobacco smoke always contains tarry products, such as pyridine. Many authorities believe that these products are as detrimental to the body as nicotine.

The fact that nicotine is poisonous and an irritant is evidence enough that smoking is harmful. In recent years experiments have led physicians to believe that much stomach trouble is due to the nicotine obtained from smoking.

The amount of nicotine absorbed by the system varies with the kind and amount of tobacco smoked. Cigarettes contain from 1.5 per cent to 2.5 per cent of nicotine. Cigar and pipe tobacco generally contain a higher percentage of nicotine—in some cases as high as 8 per cent. If the amounts of tobacco are equal, a cigar will provide most nicotine to the body, a pipe less, and a cigarette least. The use of filters in cigarette-holders and cigar-holders, as well as in pipestems, may diminish the nicotine content of smoke by one half of the normal amount.



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Output of cigars, cigarettes, and other tobacco products

Nicotine affects each person differently. The nervous person is affected most and the calm person least.

EXERCISES

1. What is alcohol?
2. How is it made? Write equations.
3. Is alcohol a stimulant? Discuss fully.
4. How does alcohol affect the body? Discuss fully.
5. What is the average annual consumption of tea and coffee per person?
6. What drug is present in coffee?
7. How does coffee affect the body?
8. Does decaffeinated coffee have all the caffeine removed?
9. What other harmful substance besides caffeine is present in coffee?
10. Compare the percentage of nicotine in cigarette, cigar, and pipe tobacco.
11. How does tobacco affect the body?

PROBLEMS FOR FURTHER STUDY

1. How does the government protect the people from harmful and useless drugs and medicines?

2. What is a patent medicine?

3. What should be on the label of drugs or medicines sold directly to the public?

4. What is the chemical composition, the effect on the body, and the values and dangers of the following drugs and medicines? (*a*) stomach remedies; (*b*) nerve remedies; (*c*) kidney and liver medicines; (*d*) blood-purifiers.

5. Find the phenol coefficient of the common antiseptics and mouthwashes.

6. What are some new types of antiseptics?

7. How is the sale of narcotics controlled?

8. What is aromatic spirit of ammonia, and how is it used as a stimulant?

UNIT EXERCISES

A. Some of the following statements are true, and some are false. On a separate sheet of paper write the word *true* for those which are true and the word *false* for those which are false. Do nothing for those of which you are doubtful. Rewrite the false statements so that they are true.

1. Many people today believe that medicine must have a bitter taste to be of any value.

2. An antiseptic inhibits the growth of germs.

3. Mouthwashes are effective in destroying harmful germs which may be present in the mouth.

4. Iodine is a good disinfectant for minor wounds.

5. A solution of iodine loses strength as it ages.

6. In cleansing a wound the wiping and brushing action should always start at the lip of the cut and proceed away from it.

7. Never bandage a wound upon which has been placed gauze or cotton soaked with iodine.

8. Laxatives have been known to cause the appendix to burst.

9. Nervousness often causes constipation.

10. The habitual use of laxatives may cause constipation.

11. Every person should have one good bowel movement a day.

12. Bulk-producing laxatives relieve constipation by increasing the peristaltic movements of the intestines.

13. Lubricants are probably the least objectionable of all laxatives.

14. Russian mineral oil comes from Russia.

15. If a drug is present in a laxative, its presence must be clearly stated on the label.

16. Laxatives which stimulate the nerves of the intestines are the most harmful type of laxatives.

17. One violent laxative is safer to take than two mild laxatives.

18. Saline laxatives relieve constipation by drawing water from surrounding tissue and thereby increasing the fluidity of the feces.

19. Natural roughage aids in producing constipation.

20. Sluggish elimination may often be corrected by drinking several glasses of warm water half an hour before breakfast.

21. A chronic headache usually indicates a serious condition in the functioning of the body.

22. The care of an alkali burn requires first the neutralization of the alkali with hydrochloric acid.

23. Sunburn requires different treatment from that of the ordinary heat burn.

24. Colds are caused by exposure to cold temperatures.

25. A person with a cold should always drink water in which a small amount of baking soda has been dissolved.

26. Nose drops and sprays are dangerous in that they may be swallowed and cause digestive disturbances.

27. Gargles have little or no value in curing a cold.

28. When a person feels a cold developing, he should immediately take a laxative.

29. After the first successful use of ether as an anesthetic, it was immediately adopted as an anesthetic by the medical profession.

30. $NH_4NO_3 + \text{heat} \longrightarrow N_2O + 2\,H_2O$. This is the equation for the preparation of ether.

31. Anesthetics have greatly aided in the alleviation of human suffering.

32. Opium is a chemical compound.

33. Marijuana is obtained from opium.

34. It is illegal to sell narcotics except when they are prescribed by physicians.

35. "Novocain" is used as a local anesthetic.

36. Soluble bromide compounds are good hypnotics because the bromine ion has a quieting effect upon the nerves.

37. $C_6H_{12}O_6 \longrightarrow 2\,C_2H_5OH + 2\,CO_2$. This is the equation for the preparation of ethyl alcohol.

38. Alcohol is a hypnotic.

39. Alcohol must go through the digestive process, like any other food.

40. Alcohol slows up a person's reaction time.

41. Alcohol causes the body to become warmer.

42. Coffee is more apt to have undesirable effects upon highly nervous people than upon persons with calm temperaments.

43. If the nicotine from a cigar were injected into the blood stream of a person, it would prove fatal.

44. When tobacco is smoked, only a small amount of the nicotine finds its way into the body.

45. If equal quantities of tobacco are smoked, the cigarette-smoker probably absorbs the most nicotine.

46. Filters in cigarette-holders and cigar-holders are useless in filtering out the nicotine and tarry products of smoke.

B. The statements which follow are incomplete. On a separate sheet of paper write whatever is necessary to complete each statement correctly. Do not write in this book.

1. The father of clean surgery is --(?)--.

2. A substance which will kill germs is called (a, an) --(?)--.

3. The ratio of the power of a given dilution of a disinfectant to kill a particular germ to the power of the same dilution of phenol to kill the same germ is called the --(?)-- of the disinfectant.

4. Tincture of iodine is made by dissolving crystals of iodine in --(?)--.

5. A mild antiseptic which may be used in the eye is --(?)--.

6. In dressing a wound great care should be taken to be certain that the hands, cotton, gauze, water, etc. are --(?)--.

7. One of the most harmful laxatives is that containing the toxic drug called --(?)--.

8. The formula of epsom salts, a saline laxative, is --(?)--.

9. The formula for milk of magnesia is --(?)--.

10. Three common causes of headaches are --(?)--, --(?)--, and --(?)--.

11. Three harmful drugs which are constituents of commonly sold pain-relievers are --(?)--, --(?)--, and --(?)--.

12. One of the best substances to use in the treatment of burns is --(?)-- acid.

13. In treating an acid burn the first procedure is that of neutralizing the acid with --(?)--.

14. Two substances commonly found in cold tablets and powders are --(?)-- and --(?)--.

15. Three commonly used anesthetics are --(?)--, --(?)--, and --(?)--.

16. Nitrous oxide is commonly referred to as --(?)--.

17. The drug in marijuana is called --(?)--.

18. A derivative of urea which is used as a hypnotic is --(?)--.

19. The habit-forming drug in coffee is called --(?)--.

20. Two effects of tea and coffee on the body are --(?)-- and --(?)--.

REFERENCES FOR FURTHER READING

BUCHANAN, ESTELLE D., and BUCHANAN, ROBERT E. *Bacteriology.* The Macmillan Company, New York, 1931.

COBB, WALTER FRANK. *Everyday First Aid.* D. Appleton-Century Company, Inc., New York, 1937.

CORRADINI, ROBERT E. *Narcotics and Youth Today.* Foundation for Narcotics Research and Information, Inc., New York, 1934.

CRAMP, ARTHUR J. *Nostrums and Quackery*, Vol. II. American Medical Association Press, Chicago, 1921.

FISHBEIN, MORRIS. *Fads and Quackery in Healing.* Blue Ribbon Books, Inc., Garden City, New York, 1932.

FÜLÖP-MILLER, RENÉ. *Triumph over Pain.* Literary Guild of America, Inc., New York, 1938.

FURNAS, C. C. *The Next Hundred Years.* Reynal & Hitchcock, New York, 1936.

HOLMES, HARRY N. *Out of the Test Tube.* Emerson Books, Inc., New York, 1935.

MCCULLOCH, ERNEST C. *Disinfection and Sterilization*, Lea & Febiger, Philadelphia, 1936.

MCCULLUM, E. V., and BECKER, J. E. *Food, Nutrition, and Health.* The Johns Hopkins Press, Baltimore, 1934.

STIEGLITZ, JULIUS, and others. *Chemistry in Medicine.* The Chemical Foundation, Inc., New York, 1928.

WILLIAMS, HENRY S. *Drugs against Men.* Robert M. McBride & Company, New York, 1935.

Home Medicine Cabinet, United States Department of Labor Bulletin, Washington, D.C.

UNIT 16

The Chemistry of Cosmetics

The use of cosmetics is not limited to modern times. Archeological discoveries have brought to light the fact that cosmetics were used many years before Christ. Perfumes, creams, hair dyes, rouges, powders, and many other beauty preparations were not uncommon. The formulas of many of these ancient cosmetics are comparable to those of our own times.

History reveals that men and women have always searched for the fountain of youth. The only difference between the search for beauty today and that of several thousand years ago is that, in modern times, scientific invention and discovery have made it possible for more people to use cosmetic preparations.

Mankind has had many peculiar beliefs about how beauty and youthfulness can be gained and preserved. At one time in history it was thought that somewhere in the world there was a fountain of youth. A person who bathed in this fountain was supposed to have immediate and everlasting youth and beauty. Even today we find some persons who place great confidence in the ability of certain preparations to produce magical transformations.

Preparations used as aids to beauty are classed as cosmetics. The commercialization of beauty and the demands of people for a variety of beauty aids have resulted in a large increase in the kinds of cosmetics. It is estimated that over two billion dollars a year is spent for beauty preparations. The cosmetic industry has become a gigantic business. One cannot listen to the radio or read newspapers and magazines without becoming aware of the enormous emphasis on cosmetic advertising.

Your understanding of the term *cosmetics* probably needs to be broadened. Cosmetics are too often thought of as including only decorative preparations, such as lipsticks, rouges, and powders. However, you should know that soaps, dentrifices, and shaving preparations are also classed as cosmetics.

Most of us would be unwilling to go back to the time when cosmetics were available only to a privileged few. Most of us recognize that beauty preparations have been an important force in the improvement of the general appearance of people. We should be aware of the fact that cosmetics have been a valuable influence in the improvement of society.

This vanity case is an attractive and convenient means for carrying cosmetics

Ewing Galloway

PURPOSES TO BE ACHIEVED

1. To become familiar with some of the ingredients of the most common cosmetics.
2. To learn the function of cosmetics.
3. To discover how cosmetics can be used wisely.
4. To become aware of the dangers involved in the use of cosmetics.
5. To learn how to buy cosmetics intelligently.
6. To learn how cosmetics may be prepared in the home.

PROBLEMS TO BE SOLVED

1. What is the composition of the many preparations classed as cosmetics?
2. How are cosmetics made?
3. How much does it cost to manufacture cosmetics?
4. How do the actual values of cosmetics compare with the advertised claims?
5. What dangers and values may result from the use of cosmetics?
6. What are the possibilities of home manufacture?

Solutions to the problems listed above will be found in the discussions of the following commonly used cosmetics:

1. Face creams
2. Face powders
3. Hand lotions and creams
4. Nail preparations
5. Make-up preparations
6. Dentrifices
7. Shaving preparations
8. Toilet soaps
9. Hair preparations
10. Deodorants and depilatories

Face Creams

The kinds of face creams. There are many different kinds of face creams. The most important ones, which will be considered in this discussion, are cold, cleansing, vanishing, tissue, bleaching, and suntan creams.

All creams, except vanishing cream, are similar in that they are made from (1) liquid oils, such as olive oil, mineral oil, and almond oil; (2) solid waxes or greases, such as white beeswax, petroleum, paraffin, lanolin from sheep's wool, and spermaceti from the head of sperm whales; (3) water or rose water; (4) an emulsifier, such as borax (sodium tetraborate); (5) a perfume.

Variations in the kinds and percentages of these chemicals account for the differences between the types of face creams. Thus cold cream may have the same ingredients as cleansing cream but usually contains more water and a smaller percentage of the liquid oils. Tissue cream is generally made with almond oil or olive oil as part of the liquid oils and lanolin, cocoa butter, or cetyl alcohol as part of the solid waxes and greases. In addition, tissue creams often have witch hazel in place of some of the required water. Bleaching creams are the same as ordinary cold or cleansing cream with the exception that such substances as hydrogen peroxide, ammoniated mercury, mercuric chloride, or lactic acid are added to produce the bleaching action. Suntan creams are generally fortified with such chemicals as quinine sulfate, alcohol, and zinc oxide. Vanishing cream contains some of the same oil and wax ingredients as other face creams but differs from them in that it contains a soft soap made by the reaction between stearic acid (a fatty acid) and potassium hydroxide.

Ewing Galloway

Cosmetics bring out individual characteristics

How to make face creams. There are so many different kinds of face creams that it would not be feasible here to give formulas for all of them. However, you should understand the general principles involved in making creams. Home or laboratory manufacture is essentially the same as that employed by the large cosmetic companies.

The general method used in making creams is as follows: In a double boiler melt completely the waxes. Then slowly, while stirring, add the mixed liquid oils and greases. When these are thoroughly mixed and dissolved, the double boiler should be removed from the fire. In another pan heat the other liquid to be added, such as the water, witch hazel, or rose water, and dissolve in this liquid the emulsifying agent (usually borax). Add this aqueous solution, which should have a temperature of about 80° C, to the wax and oil solution, stirring rapidly. When the temperature drops to from 40° to 50° C, add the perfume. Formulas and more specific directions for making creams will be found in books referred to at the end of this unit or in your laboratory manual.

Cost. The cost of creams will necessarily vary with the ingredients that are used. The formula listed below is one which is commonly used in making cold cream. This formula may be used to prepare cold cream according to the directions given above. The costs given are based upon the retail prices of each chemical used in making enough cream to fill the average-size jar of $3\frac{1}{2}$ ounces.

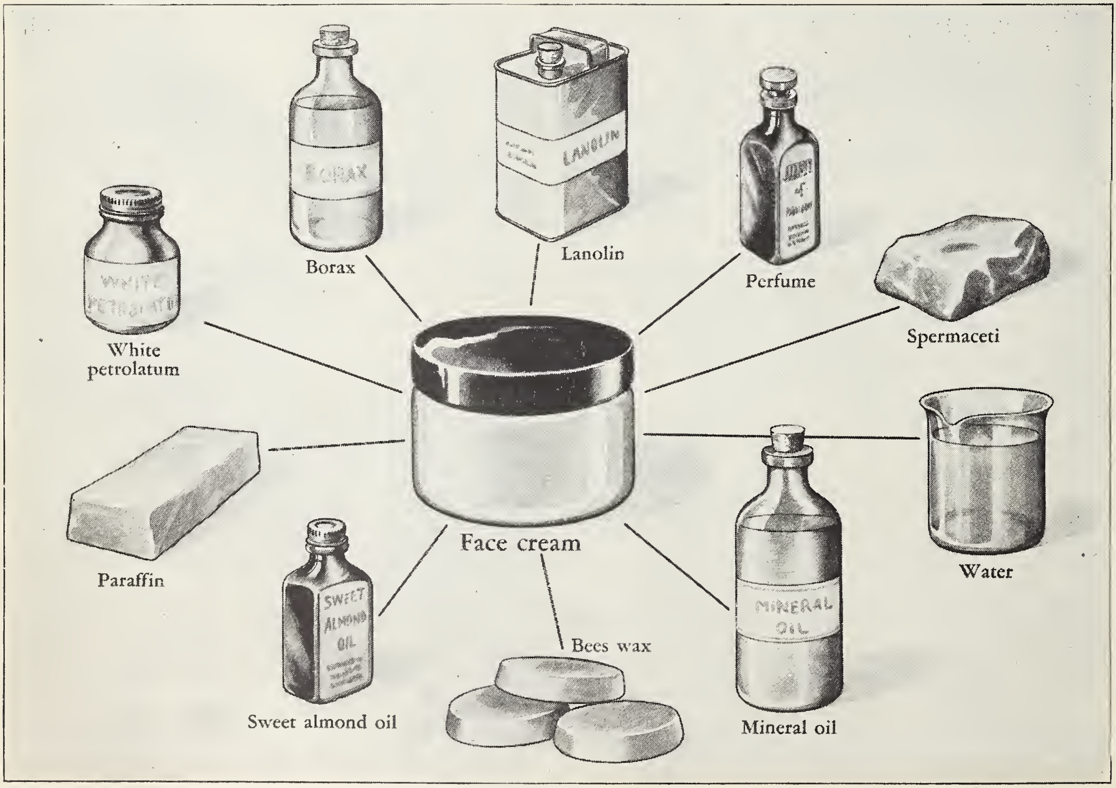
Ingredient	Weight in Grams	Retail Cost
Spermaceti	11	$.02
White beeswax	7	.03
White mineral oil	56	.05
Water	17	.00
Borax	0.5	.005
	Total cost	$.105

Why use face creams? There are many who would have you believe that cosmetic creams can perform miracles. Although the right kinds of creams used in the right way are definitely beneficial to the skin, there are many claims being made today which are not justified on the basis of scientific evidence.

Skin creams serve four different purposes.

1. To lubricate the skin. This helps to make it soft and pliable.

These materials are used to make face creams. Can you suggest other uses for some of these substances?



Ewing Galloway

Applying face cream

2. To cleanse the skin. A cream which liquefies at body temperature will take up the surface dirt of the skin. The greasy film may be removed with a cloth or cleansing tissue.

3. To encourage massaging of the skin. Many women would fail to massage the skin if they did not habitually apply a cream. Correct massaging stimulates the glands and the blood circulation, which helps to keep the skin healthy and vibrant.

4. To help to protect the skin against the weather. Cream which is left on the face protects the skin against wind and sunburn.

Can face creams replace soap and water? The question of whether or not face creams are effective cleansing agents has been debated pro and con. While it is true that cold cream will remove some surface dirt, it has been definitely proved that soap and warm water will cleanse the skin much more effectively. Face creams are best applied after the skin has been thoroughly cleansed with soap and water and copiously rinsed with clean water.

Special ingredients have little value. New brands of cream are constantly being placed on the market. Manufacturers depend upon novel methods to attract the public eye. Creams that contain cucumber, turtle, and avocado oils, and many other ingredients are said to contain vitamins and hormones. Scientific experiments do not prove that these chemicals have any value when they are applied externally to the skin.

Lanolin, the ideal skin-softener. The use of a face cream for what it is able to do is to be commended, but its use with the hope that it will perform miracles should be discouraged. If one product were to be widely advertised, that product should be lanolin, the fat of sheep's wool. Lanolin is probably the best skin lubricator and softener; yet this fact is rarely mentioned in advertising copy. Face creams which contain lanolin are usually considered the best ones to use. Lanolin contains cholesterol, a natural ingredient found in the skin.

Washing face with soap and water

Ewing Galloway

Vanishing creams. The use of vanishing cream as a powder base is on the decline. Because vanishing cream is made by the reaction between stearic acid and an alkali (usually potassium hydroxide), it is essentially a soap. It differs from soap in that less alkali is used than in soap, which leaves some free stearic acid in the mixture. The use of vanishing cream may be compared, at least to some degree, to rubbing the face with a cake of soap.

Dangers of bleaching creams. Bleaching and freckle creams and lotions may be so weak that they are ineffective, or they may be so strong that they are dangerous. The pigment of the skin is found between the two layers of the skin—the epidermis and the dermis. Freckles and darkness of the skin are caused by an overabundance of pigment. The more pigment in the skin, the harder it is for the sun to penetrate the skin and cause burning. Dark-complexioned people have more pigment in their skin than blondes and therefore do not burn easily. Mild bleaching agents, such as lemon juice (citric acid), hydrogen peroxide, and lactic acid, may have a slight bleaching effect on the pigment, but their action is only temporary in its effect. Strong bleaching agents, such as ammoniated mercury and bichloride of mercury, act to remove the layer of pigment. Such removal of the pigment is done with great irritation to the skin, and infection is possible. Many persons have been disfigured for life because of the use of strong bleaches.

The prevention of sunburn. Sunlight, in the right amount, is beneficial to the body. A good coat of tan is considered desirable and healthful, but overexposure to sunlight, which produces sunburn, is painful, injurious, and unhealthful. If one wishes to acquire a coat of tan, he should acquire it gradually by carefully avoiding overexposure. However, there are chemical preparations which, when applied to the skin, aid in attaining a coat of tan without the painful experience of sunburn.

Some suntan preparations are effective, while others are of little value. The best ones partially absorb the ultraviolet rays of the sunlight and also help to reflect the sunlight. Remember that even when such products are used, discretion in the first exposure to strong sunlight is necessary.

Some of the chemicals which are effective against sunburn are

1. *Salol ointment.* To make 10 ounces of this preparation, dissolve 1 ounce of phenyl salicylate in the minimum amount of liquid petrolatum and make up to 10 ounces with anhydrous toilet lanolin.

2. *Esculin* ($C_{15}H_{16}O_9 \cdot 1\frac{1}{2}\,H_2O$). Esculin is obtained from the inner bark of the horse-chestnut tree; it is fluorescent and absorbs ultraviolet rays. This ingredient is found in several commercially compounded sunburn preventives. Preparations containing this chemical can be made from formulas found in the references at the end of this unit.

3. Other effective chemicals are quinine sulfate, quinine acid sulfate, quinine hydrochloride, and zinc oxide.

4. For those who do not burn easily, toilet lanolin may be used.

Getting suntan on a beach

Ewing Galloway

Sunburns may prove very serious, and every precaution should be used to prevent overexposure to the sun's rays. It should be remembered that it is possible to get sunburned on a cloudy day. The treatment of sunburns is described on page 209.

Buying a face cream. The facts that have been given here should be invaluable to you in the purchasing of creams. If you have considered carefully what you can expect a face cream to do for your skin, you will not be misled by exaggerated statements to the effect that some new ingredient will perform miracles. It is folly to believe that any new chemical will create beauty.

Materials from which creams are made are not expensive. Good face creams can be made for 60 cents a pound. However, you cannot expect to buy prepared creams at the price of the ingredients. Commercially prepared creams may be purchased at a price of anywhere from $1 to $25 a pound. The difference in the price is not to any great degree dependent upon the kinds or quality of the materials used but rather upon such factors as packaging, labor, advertising, profit, and general overhead.

If a woman can find a reasonably priced face cream which is suitable to her skin, such a cream will be just as beneficial to her skin as a higher-priced cream. It is usually more economical to buy face creams in half-pound or one-pound jars.

Making a face cream at home. Not only is it possible to manufacture creams in the home, but many people claim that it can be done more successfully than when it is made by commercial processes. Materials can be obtained in any drugstore, and the equipment necessary can be found in any kitchen. There are excellent formulas in a number of references listed at the end of this unit. These formulas are for those who particularly enjoy making things at home. Though you can save money by preparing your own face creams at home, it is possible to obtain satisfactory creams in stores at reasonable prices.

EXERCISES

1. Name the different kinds of face creams.

2. What are the five kinds of ingredients used to make face creams, except vanishing cream?

3. In what ways do the ingredients differ in the kinds of face creams which are sold?

4. Describe in detail how a face cream is made.

Ewing Galloway

You can make your own face cream

5. What is the cost of the ingredients in a three-ounce or four-ounce jar of face cream? What is the selling price? What factors are responsible for this difference in price?

6. What are the four purposes of face creams?

7. Is face cream unsurpassed as a skin-cleanser?

8. Of what value are special ingredients, such as avocado oil, in face creams?

9. Discuss the value of lanolin as a skin-softener.

10. Essentially what is vanishing cream? How is it made?

11. Why are bleaching creams dangerous?

12. Is it possible to bleach the skin safely? Why or why not?

13. Are sunburn creams effective in preventing sunburn? How can it be prevented?

14. How can you be an intelligent buyer of face creams?

Face Powders

The value of a face powder. The purposes of face powder are to correct a shiny appearance of the face and to mask any slight imperfection of the skin. In performing these functions, powders give the skin a more pleasing appearance.

If a face powder is to perform these purposes, it must have four qualities:

Underwood & Underwood

Putting perfume in face powder and then putting the powder in a drum for mixing, after which it will be ready for boxing

1. Covering power.
2. Slip; that is, it must move, or spread, easily on the skin.
3. Adhesiveness; that is, it must adhere to the skin and remain for a reasonable length of time.
4. Absorbency, that is, the quality of absorbing perspiration and skin oils, as well as that of acting as a binder for the color and perfume.

The composition of face powders. Chemicals commonly used for covering power are titanium dioxide (TiO_2) and zinc oxide. Titanium dioxide has three times the covering power of zinc oxide. Talc, or hydrated magnesium silicate ($Mg_3Si_4O_{11} \cdot H_2O$), has been found to be the best substance to provide slip; and zinc, magnesium, and calcium stearates and kaolin (clay, aluminum silicate, $Al_2O_3 \cdot 2\,SiO_2 \cdot 2\,H_2O$) are most commonly used for adhesiveness. Zinc stearate ($Zn(C_{17}H_{35}COO)_2$) may be irritating to the skin, and it is being replaced by magnesium stearate. For absorbency, magnesium and calcium carbonate are used.

Face powder is sometimes classified as heavy, medium, and light in reference to its covering power. This classification is often misinterpreted as referring to the weight of the powder. The complexion of one person may demand a powder of light covering power, while that of another may require one of heavy covering power.

How to select a face powder. There are many factors which affect the selection of a powder. Among them are the climate, the color of the skin, and the natural oiliness of the skin. In selecting a powder, you should bear in mind that a little experimentation on your part will make it possible to find a powder of such texture that it will blend with and meet the conditions of your skin. If the skin is unusually dry, a powder to which an oil has been added will tend to compensate for the dryness.

Many myths have been circulated about face powders. One need no longer fear metallic poisoning because poisonous metallic compounds are no longer used as covering agents. It has been said that powder clogs the pores of the skin, but scientific evidence does not support this belief. Starches are not desirable in face powders because of the possibility of fermentation, with a consequent irritation to the skin. Starch powders do not clog the pores. There is no evidence to support the belief that face powder causes blackheads and pimples.

Good face powder need not be expensive. The ingredients are all reasonably priced, and there is no reason why you cannot find a powder of the right texture for your skin at a very moderate price. Fancy boxes do not make a good face powder. Many boxes of powder are incompletely filled; hence it is advisable to buy powder by weight.

Talcum powder is generally less expensive than face powder because it does not contain so many different ingredients. The best quality of talcum is chemically pure talc to which perfume has been added. It may be purchased at any drugstore.

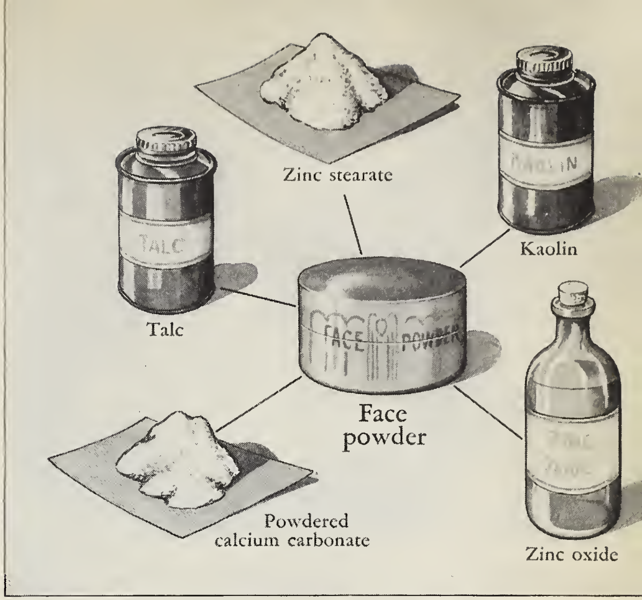
Powders can be made in the home if desirable. Methods of manufacture will be found in several of the references listed at the end of this unit.

EXERCISES

1. What are the purposes of face powder?
2. What qualities must a face powder have?
3. What chemical compounds provide the four essential qualities of face powder?

From rocks such as these talcum powder is made. A talc mine near Spragueville, New York

Ewing Galloway



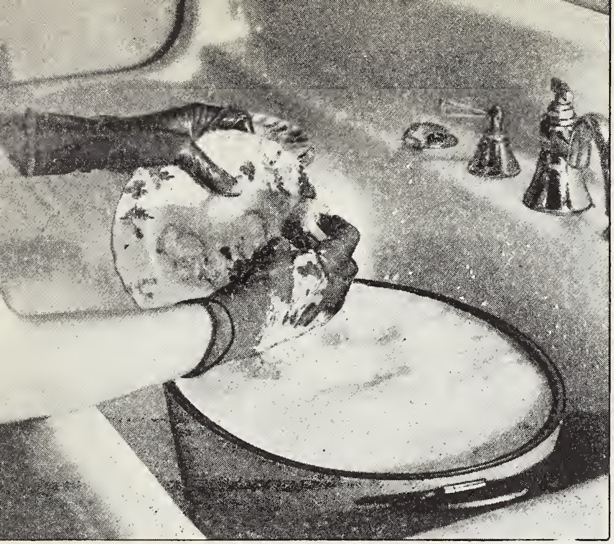
These inexpensive substances are used in making face powder

4. How should one go about selecting a face powder?
5. What dangers are connected with the use of face powders?

Hand Lotions and Creams

Beautifying the hands. Almost every person washes his hands several times a day. Many women especially, because they wash dishes and launder clothing, immerse their hands in water for long periods of time. When such practices continue, the natural oils of the skin are removed, and the free alkali of the soap will cause irritation of the skin. This results in roughness and chapping of the skin. Those who desire hands that look well and that are soft will find that lotions and creams will be beneficial in overcoming this condition. Much can be done by seeing that the hands are not immersed in water too frequently for more than ten minutes at a time, by drying the hands thoroughly at all times, and by massaging the hands regularly with a good hand lotion or cream. Such preparations are valuable only in lubricating the skin, thus relieving roughness and chapping.

Making a glycerin hand lotion. Glycerin lotions are the most common type of hand lotions. Such a preparation may be simply glycerin and rose water, or it may be a mucilage solution of a starchy gum, such as tragacanth, obtained from an Oriental tree,



Ewing Galloway

Protection of the hands, with rubber gloves, from prolonged immersion in water helps to reduce roughness and chapping

to which are added glycerin and other chemicals, such as boric acid and witch hazel. This type of lotion is simple to make and is inexpensive. The following formula may be prepared in the home:

Water	4 ounces
Tragacanth	$\frac{1}{10}$ ounce
Witch hazel	4 ounces
Glycerin	2 ounces
Boric acid	$\frac{1}{2}$ ounce

Add the tragacanth and the boric acid to the water and allow the mixture to soak for 12 hours, with occasional shaking. Add the witch hazel and glycerin and shake well. Strain through muslin. Add perfume, such as oil of rose or lavender, to suit.

Comparative values of hand preparations. Much has been said about glycerin lotions. Glycerin is known to cause dryness of the skin because it absorbs water from it. This harmful effect is probably negligible in most lotions because the glycerin is greatly diluted by the other ingredients.

Another type of hand lotion is the kind which evaporates in a few seconds. Busy women welcome a lotion which can be quickly applied. Such a lotion may feel stimulating to the hands, owing to the cooling effect of evaporation, but it can be of little value in softening the skin. Lotions that evaporate quickly tend to cause the skin to become dry and rough.

Hand creams are similar to face creams and are usually made of the same substances. The fact that lanolin is the best skin-softener makes it widely used in the best hand creams. Such a cream, if frequently used with stimulating massage, will result in soft hands. Massage, of course, is essential.

In purchasing a lotion or cream, you should bear in mind that it need not be expensive to be good. Excellent results may be obtained from the use of toilet lanolin or olive oil, both of which may be bought at a reasonable price.

If the hands are massaged thoroughly with a cream or with toilet lanolin every night before retiring, they will remain soft and smooth.

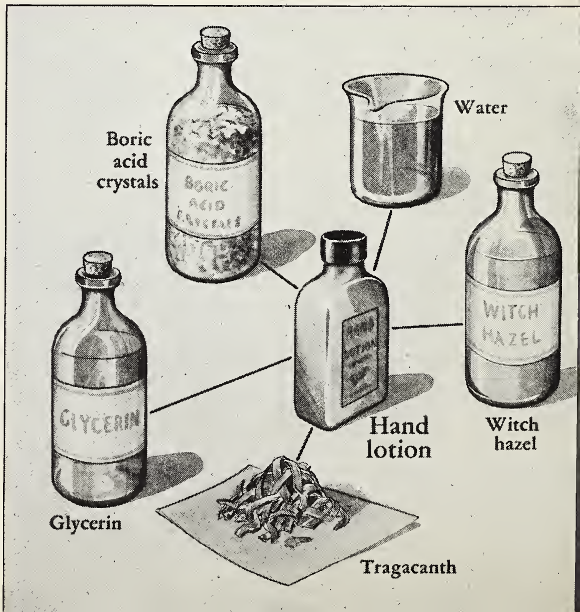
EXERCISES

1. Why do women frequently have rough, chapped hands?
2. How can rough hands be avoided?
3. How are glycerin hand lotions made?
4. Compare the value of glycerin lotions, quick-drying lotions, and hand creams.

Nail Preparations

Nail preparations. Many young people ruin their chances of making a pleasing personal appearance because they neglect the care of their fingernails. Modern preparations, which are reasonable in price and convenient to use, are available to anyone who

Substances used in making the glycerin type of hand lotions



Ewing Galloway

The condition of the hands will be greatly improved if they are thoroughly massaged every day with a good hand lotion

desires them. There is no excuse for dirty, unkept fingernails. The most common preparations for the care of the fingernails include nail polish, cuticle-remover, nail white, polish-remover, and nail bleach.

The composition and use of nail preparations. Not many years ago the only *nail polish* used was a powder consisting of tin oxide mixed with talc. When this powder was used in buffing the nails, they became lustrous. Today an entirely different preparation is used. Modern nail enamel is a nitrocellulose lacquer which is composed of a base substance, such as nitrocellulose film or pyroxylin; a solvent, such as acetone or alcohol; a spreader, such as amyl acetate; and a dye of the desired color.

The statement has been made that such a lacquer should not be left on the nails for too long a time because it does not allow the nails to "breathe." There is no evidence to support this statement; in fact, it is known that the nails do not "breathe."

Cuticle-removers are effective, but, if too concentrated, they may be dangerous. They probably remove the cuticle more evenly than it can be removed by cutting with scissors. The ingredients commonly found in these preparations are potassium hydroxide, glycerin, and water. To avoid ill effects after using cuticle-removers, you should immerse the fingers in vinegar to neutralize the hydroxide and then apply olive oil to the cuticle.

Nail white is composed of a whitening agent, such as zinc oxide or titanium dioxide, mixed with water and a mucilage to form a paste.

Nail-polish remover consists of acetone or ethyl acetate, to which an oil and perfume may be added. These ingredients may be mixed in the home at a very moderate cost. The following formula will serve well:

Ethyl acetate	1 ounce
Acetone	3 ounces
Olive oil or castor oil	30 drops

The vegetable oil is added because the other ingredients alone will cause the nails to dry and crack.

The appearance of the hands is improved through the proper use of manicure preparations

Ewing Galloway

Nail bleaches are made from bleaching agents, such as hydrogen peroxide, hydrochloric acid, citric acid, and oxalic acid. The poisonous effect of oxalic acid and the corrosive action of hydrochloric acid make their use inadvisable. Bleaches containing peroxide and citric acid are weak, but, if used consistently, they are effective.

EXERCISES

1. What are the materials used to make nail enamel?
2. What are the constituents of cuticle-removers? of nail white?
3. How may you or your druggist mix your own nail-polish remover?
4. What chemical compounds are used for nail bleaches?

Make-up Preparations

Lipstick, rouge, and mascara. In addition to powder, milady often uses lipstick, rouge, and mascara for her make-up. Lipstick is merely a thick grade of cream or wax in which a dye has been dissolved. The dyes commonly used are "Mercurochrome," aniline dyes, lake dyes, and bromoacid. Consistent use of a "Mercurochrome" lipstick, which contains a poisonous mercury salt, is not advisable. Bromoacid is a dye used to color indelible lipstick. This is effective, but for some people with sensitive skin it may cause irritation of the lips. Aniline dyes are poisonous, and lipsticks containing them should be used with care. They should not be used upon lips that are cracked or irritated. Lake colors are generally harmless. The cost of the materials used to make lipstick is very small, rarely exceeding 5 cents per stick.

This chemist is determining the melting characteristics of lipstick to ensure ease and uniformity of application

Colgate-Palmolive-Peet

Underwood & Underwood

Making lipstick. One girl is pouring the liquid into a mold, and another girl is taking the material out of the mold in the form of a lipstick

Rouge may be obtained in cream, powder, or cake form. The cream type is made by adding a dye to the usual face-cream formula. The powdered form is obtained by adding a dye to face powder; if water is added to make a paste, this form will dry to become cake rouge. Some dyes, especially mercury dyes, may cause irritation of the skin if your skin is allergic to them. You should use the kind of rouge which does not irritate your skin. Rouge should cost but little more to make than ordinary face powder.

Mascara is applied to the eyelashes by some women to improve the looks of their eyes. It is made by adding a black dye to a wax or "Vaseline" base. If an aniline dye or silver nitrate is used in its preparation, there is great danger of ruining or destroying the eyesight. Only mascara colored with lampblack, or carbon black, is safe to use.

EXERCISES

1. What substances are used to make lipstick? rouge? mascara?

2. What dangers are connected with the use of lipstick, rouge, and mascara?

Dentifrices

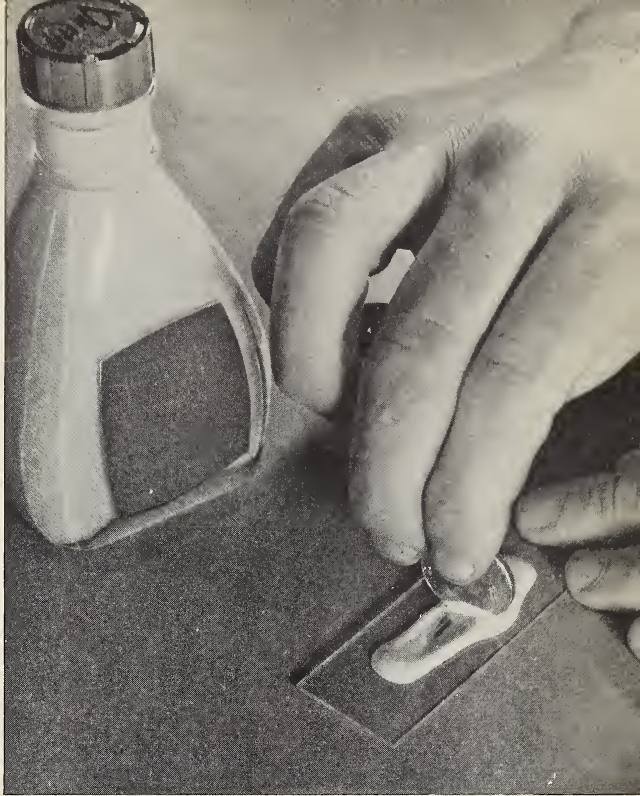
Tooth pastes, tooth powders, and liquid dentifrices. These preparations are useful only in cleaning and polishing the teeth. Nothing more can be expected from them. Some advertisements and radio patter would lead you to believe that some dentifrices will destroy harmful germs in the mouth, correct acidity, prevent or cure pyorrhea, and alleviate halitosis, or bad breath. When tooth preparations are relied upon for such conditions of the mouth, great danger may result because the condition, which should be treated by a physician or a dentist, may become acute if neglected.

What ingredients are used in dentifrices? There is nothing secret or magical about dentifrices. They are all made of simple ingredients. The most common substance used as a base in tooth powders is pure precipitated chalk ($CaCO_3$), to which is added a small amount of other chemicals, such as soap, sugar or saccharine, and flavoring. Tooth paste is made by adding water, glycerin, and honey to the ingredients of the powder.

The liquid dentifrices are usually alcoholic solutions of sodium salts of the sulfonated higher alcohols, with flavoring and coloring materials. These are, in reality, soapless soaps and possess no unusual cleaning properties.

Arguments have been offered as to the relative values of the powder, paste, and liquid dentifrices. Experimental evidence does not prove that one should be preferred to the others. The main factor in tooth cleanliness is that the teeth be brushed properly at least twice a day.

The cleaning agent in a dentifrice or powder should be of such a nature that it does not scratch the teeth. The best quality precipitated chalk is an acceptable cleaning agent. Pumice is the worst and should be avoided because it is too abrasive. Any tooth preparation that contains a harsh cleaning agent should be shunned. Those which contain bleaches may have detrimental effects, and those powders which contain sodium perborate ($NaBO_3 \cdot 4H_2O$) may be irritating to the gums. Dental powders which effervesce usually contain sodium perborate. Little credence should be given to the theory that the nascent oxygen evolved is helpful.


Consumers Union

You may use this simple test to determine the abrasiveness of dentifrices

Homemade dentifrices. You need not buy an expensive dentifrice to keep the teeth clean. In fact, you need not buy a commercial product at all. A mixture of two parts of salt and one part of baking soda will do, or you may buy at any drugstore a pound of flavored precipitated chalk for from 50 to 75 cents which will last for a year.

You may make a commercial type of paste or powder at home by using this formula:

	Amount	Approximate Cost
Precipitated chalk	4 ounces	$.10
Magnesium carbonate	3 ounces	.07
Powdered sugar	1 ounce	.005
Powdered white soap	1 ounce	.05
Oil of peppermint or wintergreen	7 drops	.01
Total	9 ounces	$.235

E. I. Du Pont de Nemours & Co.

The strands of "Nylon" shown in this picture are used for the bristles in toothbrushes. In caring for the teeth, the toothbrush and the way in which you use it are much more important than the dentifrice

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If a paste is desired, add water and glycerin until the proper consistency is attained. This will make as much paste as is found in three or four of the average-size commercial tubes.

EXERCISES

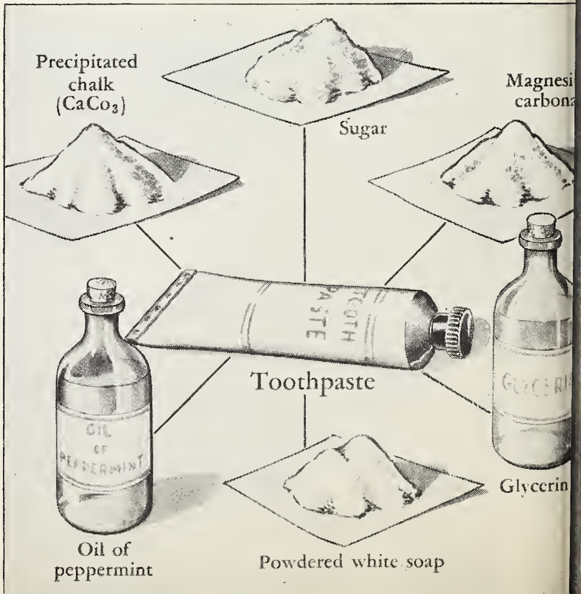
1. Compare the actual value of dentifrices with some of the advertised claims.
2. What ingredients are used in the making of dentifrices?
3. Which is preferable, a paste, a powder, or a liquid dentifrice? Discuss.
4. What cautions should be observed in the selection of a dentifrice?
5. How may a dentifrice be made in the home? Describe in detail.

Shaving Preparations

Shaving soaps. A few years ago every man had a shaving mug and a cake of soap to be used in the preparation of a lather for shaving. In recent years this same soap has appeared in the form of a stick, a powder, and a cream. The use of the mug and cake is now old-fashioned, though the new forms of soap preparations are virtually the same as the old. The chief difference lies in the amount of money you spend for these modern preparations. There are actually more shaves in two five-cent cakes of shaving soap than in one fifty-cent tube of shaving cream, and the quality is about the same. A shaving cream is a soap to which ingredients such as glycerin or lanolin are added to keep it from hardening. The methods of manufacture and the materials used in the making of soap will be discussed in the section on soaps.

Brushless shaving creams. The latest preparation used for shaving is brushless shaving cream. This shaving cream is very similar to vanishing cream in that it is made from stearic acid, oils, and greases to which potassium hydroxide is added. The value of this preparation compared to soap is not known; but if it is carefully made and if it gives you a good shave, there is no reason to believe that it will be harmful. It is more expensive to use than ordinary shaving cream.

These common materials are used in the manufacturing of tooth paste



Lotions. The abrasive action of the razor blade many times causes the skin to be irritated after shaving. In the hope of overcoming this condition, many men apply an after-shaving lotion to the face. If the proper lotion is used, the opened pores will contract, the microscopic skin abrasions will be antisepticized, and the face will be stimulated by the cooling effect of the evaporating lotion. Common ingredients used in these lotions are boric acid, alcohol, glycerin, witch hazel, and water. It is not necessary to buy an expensive lotion; witch hazel is probably the best and cheapest lotion that you could use. Cold water is an excellent astringent and is sufficient for most men.

Styptic pencils. Styptic pencils are essentially compressed alum ($KAl(SO_4)_2 \cdot 12\ H_2O$). When applied to a cut, this chemical causes the broken edges of the skin to contract, thereby stopping the flow of blood. Powdered or burnt alum, bought as such, is probably the best for this styptic action.

Shaving by electricity. The newest development for shaving, the electric shaver, eliminates the abrasive action of the sharp razor blade. Manufacturers of electric shavers claim that the continued irritation due to ordinary shaving causes scar tissue to form, making the skin rough and hard. They present evidence to support this by calling your attention to the fact that as you begin using an electric shaver this scar tissue will fall from the face like flakes of dandruff and will continue to do so for a period of several weeks. Some men find that the electric shaver will give as good a shave as any razor; others say that it does not shave close enough.

EXERCISES

1. What is the difference between cake and cream shaving soap?
2. What is brushless shaving cream?
3. What ingredients are used in shaving lotions?
4. What is the chemical composition of a styptic pencil? How does it stop bleeding?
5. Compare the electric shaver and the safety razor.

Toilet Soaps

Soap necessary for cleanliness. Soap is the greatest contribution man has made to the science of cleanliness. It has probably done more to promote health than any other substance. Man is always searching for an easy, pleasant way of doing things. The effort required to lather the skin with soap and water and then rinse it is considered unpleasant and time-consuming by some people. For this reason, search is continually being made for soap substitutes, and manufacturers have produced many preparations for which striking claims have been made. But in spite of all these preparations and all the claims that have been made for them, science has yet to find a substance which can equal soap and water for cleansing the skin.

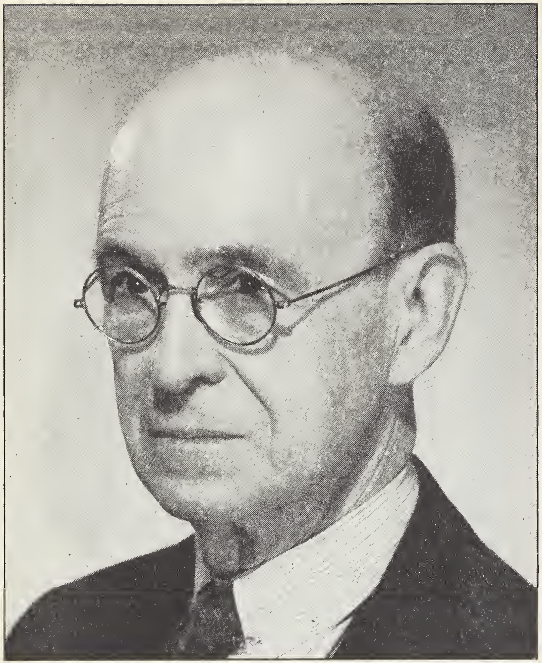
Colgate-Palmolive-Peet

This device measures the consistency, or plasticity, of shaving cream and face cream, thereby ensuring proper action when the cream is applied to the skin

The making of soap. Soap is made by the reaction of a vegetable or animal fat or oil with a base or hydroxide. A simple statement of this reaction is as follows:

$$\text{Fats} + \text{alkali} \longrightarrow \text{glycerin} + \text{soap}$$

Some of the common fats and oils used are olive oil, palm oil, cottonseed oil, beef fat, coconut oil,



Ewing Galloway

What causes baldness? Can it be prevented?

tallow, and castor oil. When a hard soap is desired, the base used is sodium hydroxide. When a soft or liquid soap is needed, potassium hydroxide is used. Refer to Unit 12 and Unit 25 for more information on the chemical nature of soap.

The manufacture of good soap for toilet purposes is an exacting process. The removal of impurities and the correct proportions of oil or fat and base demand careful processing. If too much of the base is added, the soap will be excessively alkaline, which will make it irritating to the skin.

Factors to be considered in selecting toilet soaps. The cost of soap does not necessarily determine its quality. Soap is made of inexpensive materials, and a five-cent bar may be just as good as a fifty-cent bar. Soap made from pure olive oil as the only fat or oil ingredient, to which has been added the proper amount of base, is as good a soap as you can buy. This kind of soap can be bought under the name of castile soap. Beware of castile soaps which are not labeled U.S.P., because they may or may not be made from olive oil.

Soap has some antiseptic properties. For this reason frequent washing of the hands, especially before eating, with any mild soap is advisable not only to remove dirt and grease but to destroy disease-bearing germs as well.

Transparent soap, which is made by adding glycerin to the soap mixture before it cools, has no additional cleaning value.

Soap which has air beaten into it will float, though this does not add anything to its effectiveness as a cleaning agent.

The cleansing action of soap is not fully understood. It is known that it cuts, or dissolves, grease and has the power of adsorbing, or forming a film around, particles of dirt and other particles that adhere to the skin.

EXERCISES

1. How is soap made? Write the equation for the reaction.
2. What is castile soap?
3. How may you be sure of getting pure castile soap?
4. Is there a toilet soap that has special germ-killing properties? Discuss.
5. How is transparent soap made?
6. What causes some soap to float?

Hair Preparations

Hair preparations. A head of healthy hair is much desired by everyone, but those who have it rarely appreciate it. Most of us are utterly ignorant of the scientific way of caring for the hair.

Proper care is essential in maintaining a healthy head of hair. Cleanliness is first in importance. Although no definite rule can be given, it is generally accepted that the hair should be shampooed at least once every two weeks, probably no oftener than once a week. Next in importance comes massage. It has been said that many cases of baldness could be avoided or retarded if the scalp were massaged or brushed three minutes every day. Massage and brushing bring blood to the scalp and hair, which stimulates its growth and gives it a healthful appearance. Other ways of promoting the health of the hair are to avoid tight-fitting hats, to observe proper rules of diet, to maintain normal elimination, and to use clean combs and brushes.

Dandruff is a disease of the scalp. It is contagious; and whether your scalp is oily or dry, you may contract it. As a precaution, you should insist that hats, combs, and brushes are personal accessories and should be used by no one but the owner. Many times dandruff will yield to applications of an alkaline soap. For this reason, a shampoo with tincture of green soap, a strong alkali soap dissolved in alcohol, may be found effective. If this soap does not rid the scalp of dandruff, consult a physician.

Many chemical preparations are available for the care and beautification of the hair. The most important of these are shampoos, tonics, bleaches, dyes, and oils.

Soap shampoos. The most common materials used to shampoo the hair are cake soap, liquid-soap shampoos, and "soapless shampoos." The purpose of shampooing the hair is to cleanse it thoroughly, thus making it soft and lustrous. Other claims that may be made should be looked upon with suspicion.

Liquid-soap shampoos should lather freely and quickly and should contain very little free alkali. These soaps are made like hard soap except that potassium hydroxide is used as the alkali, and frequently alcohol is added. The most common oils used are almond, olive, palm, and coconut. Although soap made from coconut oil will lather quickly, it is known to be irritating to some skins.

It is not necessary to buy an expensive liquid shampoo. One which will serve well can be made by cutting up a cake of pure castile soap in a pint of water and heating until dissolved. When cooled, this mixture will form a gel, part of which may be mixed with warm water for use as a shampoo.

Cake soap when rubbed directly on the hair is not as good for shampooing as liquid soap. This is due to the fact that the soap frequently sticks to and remains in the hair, which makes it stringy.

"Soapless shampoos." There are two kinds of "soapless shampoos"—those made from sulfonated oils and those made from sulfonated higher alcohols. When olive oil and castor oil are treated with sulfuric acid (sulfonated), the oils become soluble in water. Mixtures of these two sulfonated oils are fairly good cleansers, but they remove the natural oil from the scalp, leaving the hair dry and dull in appearance. To overcome this condition, the "soapless shampoos" are made by mixing a small amount of mineral oil with the sulfonated oils. These oil shampoos do not produce a lather.

Pure castile soap makes an excellent shampoo for the hair

The sodium salt of a sulfonated higher alcohol, such as lauryl alcohol, possesses the detergent and lathering properties of soap, although it is not a true soap. Shampoos containing this soapless cleansing agent may now be obtained. People who live in hard-water regions will find these shampoos more effective than soap, since they do not form the greasy curd which always forms when soap is used with hard water.

Rinsing the hair. Some persons rub a beaten white of an egg into the hair after a shampoo. This gives the hair an attractive luster, or sheen. It should be thoroughly rinsed out with water. Rinsing with one or two tablespoons of lemon juice or vinegar in water is recommended. Such a rinse will remove any remaining soap or excess oil and cause the hair to be soft and fluffy.

Hair tonics. The use of tonics has been based upon the claims that they will prevent baldness by stopping the falling of hair or will correct a condition of the scalp which prevents the hair from growing. Neither of these claims has any scientific foundation. Although the cause of the loss of hair in the case of premature baldness is not exactly known, there is some evidence to show that the loss may be caused either by disease or by hereditary factors. When disease is the cause of baldness, there is a possibility that the growth of the hair may be restored. When baldness is due to heredity, no method has been found to stimulate growth. Where heredity is the cause of baldness, a tonic is therefore useless. If a disease of the scalp is the cause, a diagnosis and treatment by a physician is imperative if good results are to be expected.

Most tonics contain antiseptics, such as resorcinol, salicylic acid, and compounds of arsenic, such as quinine arsenite and potassium arsenite. They also contain alcohol, oils, perfume, and many other ingredients. It is impossible to obtain a hair tonic which contains an antiseptic capable of curing all the different scalp diseases. In some cases, the antiseptics act as severe irritants to the scalp, and many serious results have been experienced from the use of tonics.

Hair bleaches and dyes. The use of hair bleaches and dyes can generally be attributed to two factors—the desire to improve personal appearance and the desire to prolong the period of youth. With the hope of improving their appearance, it is not uncommon for young people to change the color of their hair several times. Those who, in middle age or old age, have hair that has begun to turn gray sometimes use a dye or bleach to mask the gray hair. People who use such preparations are generally ignorant of their effects.

A hair bleach is usually a chemical which will release oxygen. This nascent oxygen reacts with the natural dye of the hair, changing its composition so that the hair becomes lighter in color. The most common bleach used is a solution of hydrogen peroxide and ammonia. Such a mixture when applied to the hair produces what is known as a "peroxide blonde." Although one application of this solution is not harmful, several applications are; and it must be applied frequently as the hair keeps growing out. Constant use of this bleach causes the hair to become brittle and coarse. As the applications continue, a less desirable yellow will be produced.

There are several different kinds of hair dyes—vegetable, metallic, and aniline. The vegetable dyes, are least harmful but have not proved to be successful. Pure henna, a vegetable dye which produces reddish tints, is effective as a temporary dye and is believed not to be harmful. The metallic dyes which are compounds of such metals as lead, arsenic, mercury, and copper are very dangerous to use. Aniline dyes, obtained from coal tar, are also too poisonous to use. Many people are allergic to both these dyes, and serious results both from skin irritation and from internal disorders are not infrequent. If you are determined to use a dye, select a competent operator who will give you a skin test before dyeing your hair to determine whether you are allergic to the dye to be used.

Dyes are dangerous and looked upon by many people with considerable disfavor. For this reason, some distributors are advertising rinses which restore the natural color of the hair, or they may refer to them as hair-restorers. Do not be deceived by such statements; these preparations are actually diluted dyes.

Hair oils. Many persons whose hair is dry, unruly, and lifeless use an oil, such as brilliantine, to keep it in place and make it lustrous. Preparations of this nature which are now being marketed usually consist of a light oil, such as mineral oil, odorless kerosene, sweet almond oil, and a perfume. A serviceable hair oil can be made by mixing three parts of light mineral oil with two parts of odorless kerosene and adding perfume to suit.

EXERCISES

1. How should the hair be cared for? Discuss fully.

2. What is dandruff? How can it be cured?

3. How can a liquid shampoo be made inexpensively?

4. How are "soapless shampoos" made? Are they equal in value to soap?

5. How should the hair be shampooed?

6. What causes baldness?

7. Can hair tonics and other substances prevent baldness or make the hair grow after baldness has appeared? Discuss fully.

8. What are the ingredients in hair tonics? Of what value are they to the hair and scalp?

9. What are hair bleaches? Name several common ones.

10. What are the different kinds of hair dyes?

11. What dangers may result from the use of hair dyes?

12. Are any hair dyes safe to use?

13. What do hair oils consist of?

Deodorants and Depilatories

Deodorants and astringents. You have previously learned that the body eliminates about one quart of water a day through the pores of the skin. After the water evaporates, chemicals present in the perspiration adhere to the skin and soon become rancid. Where evaporation does not take place readily, as under the arms, the putrefaction of the organic salts takes place more readily and results in a body odor.

Frequent bathing will not always prevent body odor. Each person's body functions differently, and with some, perspiration becomes rancid sooner than with others, causing a more noticeable odor. Special soaps containing phenol or any other odorous substance have no merit in eliminating body odor.

The ancients used perfumes to overcome body odor. Such a procedure would not be acceptable to our present society, because it does not completely conceal the odor.

When body odor is unusually strong, it is probably due to a physiological defect, and a physician should be consulted. Fortunately, most cases of body odor can be allayed by focusing attention on the armpits. Therefore the use of a deodorant is helpful, but a deodorant must not be substituted for the daily bath. People with a mild case of body odor sometimes find the use of a good talcum powder sufficient for their purpose. Others need an astringent to close the pores of the armpits. Most deodorants now being sold are astringents.

If an astringent is necessary, it is advisable to try first a mixture of equal parts of powdered boric acid and sodium bicarbonate, or you may make a saturated solution of these chemicals by dissolving as much of the mixture as possible in a pint of water. This solution may be applied to the armpits or may be placed in the bath water.

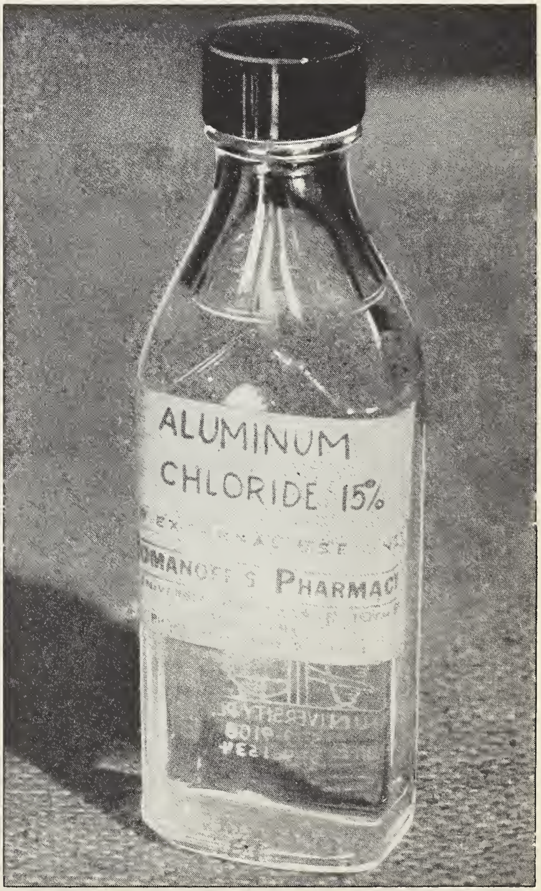
If this procedure does not remove the offensive odor, it may be necessary to apply occasionally to the armpits a 5 per cent to 15 per cent solution of aluminum chloride. The solution should be allowed to dry. Then the armpits should be washed thoroughly with soap and water. Such procedure will remove the excess chemical, thereby preventing the rotting and disintegrating of the clothing. Be sure, therefore, to wash the armpits after using this solution. A deodorant of this type should not be used for at least forty-eight hours after shaving the armpits.

Deodorant creams are of two types—those containing aluminum compounds and other astringents and those containing chemicals, such as zinc oxide, which are absorptive and slightly astringent. The creams of the first type must be rinsed off before dressing in order to protect the clothing.

Depilatories, or hair-removers. Depilatories are hair-removers. There are many different kinds; some are safe, but others are very dangerous. One common type of depilatory is a cream or powder containing sulfides of barium, calcium, or strontium. These compounds remove the hair by dissolving it. Since the structure of the skin is similar to that of the hair, these depilatories may also destroy the skin and consequently cause intense irritation. Sulfide depilatories are easily recognized because they have the odor of rotten eggs. Other dangerous depilatories are those containing thallium acetate, a deadly poison. This chemical destroys the nerve endings of the hair follicles and causes the hair to fall out. The

Any druggist will gladly prepare a solution of aluminum chloride for you for use as a deodorant

Consumers Union



hair may not grow back for from six to twelve months. Such depilatories have been known to be the direct cause of blindness, paralysis, and other equally serious disorders.

Some fairly safe ways of removing or masking objectionable hair are plucking, pulling out with wax, shaving, and bleaching. Plucking is painful and slow but effective. Heavy waxes may be applied in the molten state and, when hard, jerked from the skin, carrying with them the embedded hair. Shaving is effective, but after a time, when the hair begins to grow out, it has a rough, bristly feeling. The hair may be bleached by applying a solution of hydrogen peroxide which has been made slightly alkaline with ammonia. This method is probably the least harmful of all.

It must be thoroughly understood that none of these methods will permanently remove the hair. The only means by which hair can be permanently removed are the X ray and the electric needle. The X ray is extremely dangerous because of its effect upon the skin and body, and the use of the electric needle is very tedious and painful. The electric needle must penetrate every hair follicle to result in its destruction. It should be done by a physician who is especially skilled in the use of the electric needle. Many faces have been pitted and scarred for life by the bungling of an unskilled operator.

EXERCISES

1. How may a deodorant be made from simple chemical compounds found in almost every home?

2. What inexpensive deodorant can be made for you by your druggist? How should it be applied? Why?

3. What are the constituents of the deodorant creams?

4. Describe the several kinds of depilatories. What is the composition of each? How does each remove hair?

5. Is it safe to remove hair with an electric needle?

PROBLEMS FOR FURTHER STUDY

1. From the point of view of the problems listed under "Problems to Be Solved" at the beginning of this unit and any additional problems that the class may suggest, investigate the following cosmetics: (*a*) mouthwashes; (*b*) skin-toning lotions; (*c*) acne, blackhead, and eczema creams; (*d*) astringent lotions; (*e*) waving fluids; (*f*) bath preparations; (*g*) perfumes and toilet waters, including colognes; (*h*) facial masks; (*i*) foot preparations; (*j*) reducing creams.

2. What causes baldness?

3. What causes acne and blackheads?

4. Write a history of cosmetics.

5. List claims made for cosmetics and compare these claims with the known facts.

UNIT EXERCISES

A. On a separate sheet of paper write the word or words which correctly complete each statement. Do not write in this book.

1. All face creams, except vanishing cream, are made of water, an emulsifier, a perfume, --(?)--, and --(?)--.

2. The best skin-softener is --(?)--.

3. Three purposes served by face creams are --(?)--, --(?)--, and --(?)--.

4. Vanishing cream is essentially --(?)--.

5. Bleaching creams which contain --(?)-- compounds are very harmful to the skin.

6. Face powder must have these qualities: slip, absorbency, --(?)--, and --(?)--.

7. Roughness and chapping of the hands can be greatly reduced by protecting them from --(?)--.

8. Cuticle-removers are made of glycerin, water, and --(?)--.

9. Mascara which contains dye may cause serious --(?)-- trouble.

10. The substance most commonly used in making tooth paste or tooth powder is --(?)--.

11. A very common substance which may be found in the kitchen of any home and which will serve as an excellent tooth-cleanser is --(?)-- or --(?)--.

12. Styptic pencils are essentially $KAl(SO_4)_2 \cdot 12\,H_2O$. This compound is commonly called --(?)--.

13. Fat + alkali yields glycerin + --(?)--.

14. Pure castile soap should contain as an ingredient --(?)--.

15. The consumer is assured of pure castile soap if the label has --(?)-- on it.

16. Shampooing the hair with --(?)-- often rids the scalp of dandruff.

17. A good shampoo may be made by dissolving --(?)-- in water.

18. The principal ingredients of "soapless shampoos" are mixtures of sulfonated --(?)-- and --(?)-- oils.

19. Hair tonics, soaps, and the like are useless in the cure of baldness if the loss of the hair is due to --(?)--

20. Many tonics which purport to cure baldness contain as one of their ingredients poisonous compounds of --(?)--.

21. A common substance used as a hair bleach is --(?)--.

22. A hair dye which contains --(?)--, a coal-tar dye, may be harmful to the scalp.

23. Body odor from the armpits can usually be eliminated by applying a 5 per cent to 15 per cent solution of --(?)--.

24. An inexpensive deodorant can be made in the home by mixing equal parts of boric acid and --(?)-- and preparing a saturated solution with the mixture.

25. The depilatory which dissolves the hair is composed of barium, calcium, or strontium --(?)--.

B. On a separate sheet of paper write the word *true* for those statements which are true and the word *false* for those which are false. Do nothing for those about which you are doubtful. Rewrite the false statements so that they are true.

1. Cosmetics are very recent in their origin.

2. In making face creams it is essential that the waxes and oils be at the same temperature as the water solution when they are mixed together.

3. Because of the equipment that is needed, face creams cannot be made as successfully in the home as in a commercial manufacturing plant.

4. Only one or two ingredients in face cream are costly.

5. If face cream is used several times a day, it is not necessary to use soap to cleanse the skin.

6. Face creams containing special ingredients, such as turtle oil, vitamins, and hormones, are of no more value to the skin than creams made without these ingredients.

7. Lanolin is obtained from the root of a tree.

8. Permanent bleaching of the skin requires the removal of the upper layer of the skin.

9. Sunburn lotions have no value in preventing the skin from becoming sunburned.

10. The quality of a face cream should be judged by its cost.

11. Common talc is used in making almost all face powders.

12. The terms *heavy*, *medium*, and *light* as applied to face powder refer to the weight of the powder.

13. Statements which lead one to believe that different kinds of skin require different kinds of face powder are false.

14. Many face powders contain poisonous metallic compounds.

15. Roughness and chapping of the hands are mostly due to the wind and the sun.

16. A glycerin lotion is the best one that can be used to keep the hands soft and smooth.

17. In caring for the hands, massage is more important than a lotion.

18. Lipstick is essentially a cream or wax to which a dye has been added.

19. Brushing is much more important in the care of the teeth than the dentifrice that is used.

20. A tooth powder is more effective in cleaning the teeth than a tooth paste.

21. Owing to the addition of new ingredients, the cream type of shaving soap is much superior to the old-fashioned bar shaving soap.

22. Brushless shaving creams have acids in them which may be harmful to the skin.

23. There is no substitute for soap and water as cleansing agents.

24. A cake of soap which floats does not contain as much soap by weight as a cake of equal volume which does not float.

25. Dandruff is nothing more than a peeling and sloughing off of the skin of the scalp.

REFERENCES FOR FURTHER READING

Bennett, H. *Cosmetic Formulary.* D. Van Nostrand Company, Inc., New York, 1935.

Cades, Hazel R. *Good Looks for Girls.* Harcourt, Brace and Company, New York, 1932.

Ephraim, Jerome. *Take Care of Yourself.* Simon and Schuster, Inc., New York, 1937.

Goodman, Herman. *Cosmetic Dermatology.* McGraw-Hill Book Company, Inc., New York, 1936.

Goodman, Herman. *Principles of Professional Beauty Culture.* McGraw-Hill Book Company, Inc., New York, 1938.

Joslen, Sonya. *The Way to Beauty.* Pitman Publishing Corporation, New York, 1937.

Kallett, Arthur. *Counterfeit.* The Vanguard Press, New York, 1935.

Lapish, Edith P., and Orr, Flora G. *Be Beautiful.* D. Appleton-Century Company, Inc., New York, 1932.

Levin, Oscar L. *Keep Your Hair On.* Robert M. McBride & Company, New York, 1936.

Phillips, M. C. *Skin Deep.* The Vanguard Press, New York, 1934.

Reich, Edward, and Siegler, Carlton. *Consumer Goods.* American Book Company, New York, 1937.

Stote, Dorothy. *Making the Most of Your Looks.* Frederick A. Stokes Company, New York, 1935.

Willman, Katharine. *Beauty Begins at Home.* Grosset & Dunlap, Inc., New York, 1936.

The Chemistry of Clothing

E. I. Du Pont de Nemours & Co.

"The test-tube girl." Chemistry contributed her rayon dress and gloves, cellulose-film hat and bag, plastic scuffless heels for her shoes, "Nylon" hose, and "Lucite" plastic jewelry

The making of clothing or textile fabrics is one of the oldest of the industrial arts. Fabrics were made many centuries before the dawn of history. Even the dyeing of man-made textiles antedates history. The skins of animals were man's first clothing materials. Later he discovered that nature produced other materials which he could make into better clothing fabrics. Since those early days, man has continually found additional raw materials of nature from which he can make clothing.

Until fifty years ago, even our most ingenious artisans were unable to find any raw clothing materials except those already made by nature. Since that time, however, chemists have made many new fibers out of which new clothing materials can be woven.

The textile industry—the industry which clothes us and plays a large part in furnishing our homes—is one of the largest businesses. Chemistry enters the textile industry in countless ways. Cloak and suit manufacturers employ chemists to test their textile materials. Textile mills employ chemists to check the various processing activities. Many companies finance research departments to find new and better fabrics.

PURPOSES TO BE ACHIEVED

1. To broaden your understanding of the reasons for wearing clothing.
2. To learn the chemical properties and characteristics of the different kinds of materials used in making clothing.
3. To help you to recognize the different fabrics.
4. To assist you in buying clothing wisely and economically.
5. To learn how to care for your clothing.

PROBLEMS TO BE SOLVED

1. What is the function of clothing?
2. What are the properties and characteristics of clothing materials?
3. How are the different fabrics made?
4. How are fabrics dyed?
5. What simple chemical and physical tests may be used in identifying fabrics?
6. How should clothing be cared for?

Problem 1. What is the function of clothing?

Clothing is necessary for modern life. The use of clothing and other textile materials has accompanied the growth of civilization. Savage man either wore no clothes at all or draped himself meagerly in the skins or furs of animals. Modern life demands an extensive use of clothing for many reasons. Decency and good moral standards demand that clothing be worn. Modern living is far different from that of prehistoric times, when people lived together in patriarchal groups. Though it may be true that we wear too much clothing, people recognize the moral need for clothes to cover the naked body.

Health demands that the body be clothed. The body is equipped by nature to adjust itself partially to changes in the temperature of its environment. You have previously learned that the temperature of the body is partially controlled by the evaporation of perspiration from its surface. During cold weather this wonderful device of nature functions best with the help of clothing because clothing retards the evaporation of perspiration, and thus the heat of the body is retained. It is well known that when the temperature of the body remains abnormally low, it becomes easy for many kinds of germs to gain a foothold. You should know which fabrics protect the body best in warm and in cold weather.

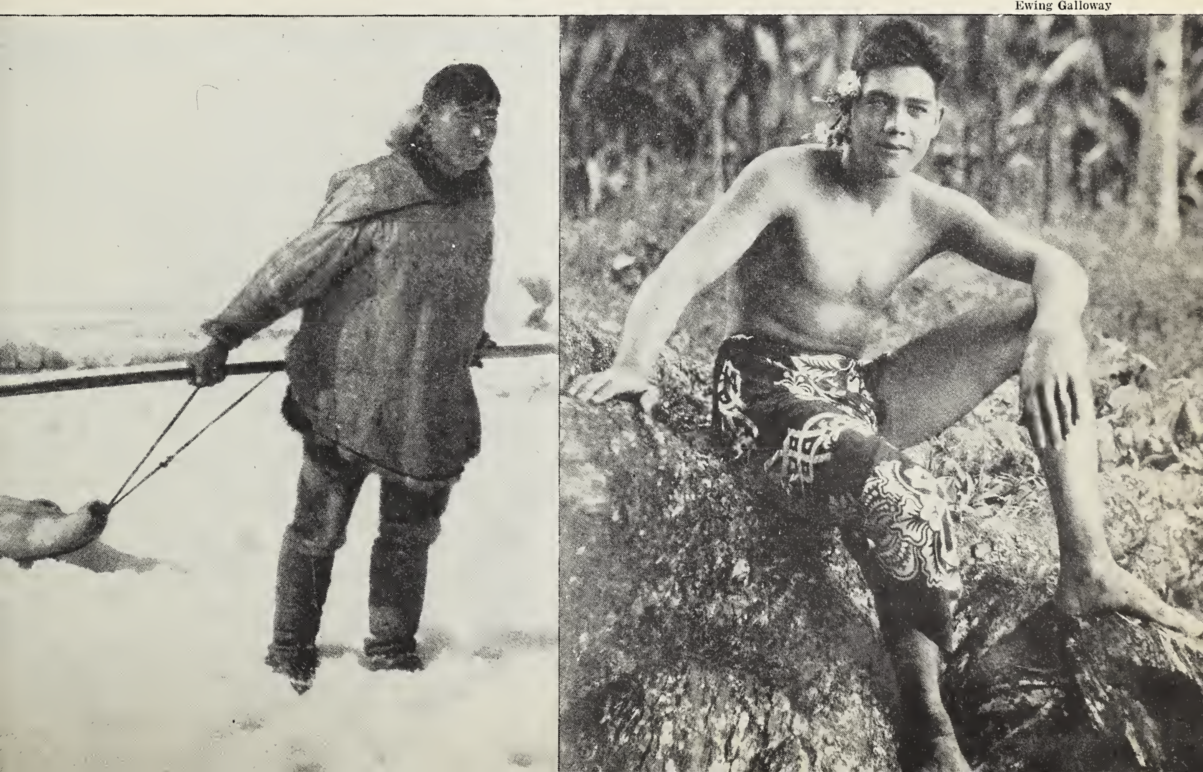
Our primitive ancestors who wore no clothing must have had a difficult and painful time recovering from scratches and other injuries to their naked bodies. The span of life was extremely short, and there is no doubt that the lack of clothing, with the attendant exposure of the person to infections of all kinds, was a principal cause of this shortness of life.

Clothes and mental health. We can even justify clothing from the standpoint of style and adornment. Both mental health and physical health will be better if a person is able to feel that he is attractive. The use of the many beautiful multicolored fabrics, products of the chemist's test tube, will help to develop that self-confidence which is an important part of mental health.

EXERCISES

1. Why does modern living demand more clothing than was formerly necessary?

2. List the ways in which clothing protects the health of the body.



The kind and amount of clothing worn by man vary with the climate

Ewing Galloway

3. What part does chemistry play in the clothing industry?

4. How have new kinds of clothing increased the joy of living?

Problem 2. What are the properties and characteristics of clothing materials?

Sources of clothing materials. Most clothing and other textile materials are made from the natural fibers of cotton, wool, silk, and linen and from the artificial fiber rayon. However, there are other natural and artificial fibers and materials which are used. Furs and leathers made from the skins of animals are used extensively. New artificial fabrics of much promise are "Nylon" and "Vinyon," new synthetic silks. "Woolstra," or lanital, a synthetic wool made from skim milk, and "Vistra," a synthetic cotton made from wood, have been used to replace the natural fibers. Clothing is made even from mineral substances, such as spun glass, silver, gold, and asbestos.

You will be interested in discovering the properties and characteristics of these many fabrics. This discussion will help you to answer many questions about them.

Fabrics made from animal fibers. Animals furnish many fine fibers out of which we can weave clothing materials. The most important of these are the hair fibers, such as wool from sheep, and silk fibers from the cocoon of the silkworm. All animal fibers are proteins. The exact chemical composition of animal fibers, such as wool and silk, is not known. However, chemists do know that animal fibers are made up of amino acid groups.

Wool, the warm fiber. The chemical elements in wool are oxygen, nitrogen, hydrogen, sulfur, and carbon. The molecules of wool fibers are big, containing dozens of atoms of each of the foregoing elements. However, wool is different from compounds of definite composition, since different wool fibers do not always have the same composition. The presence of protein in all wool is proved by the fact that any wool fiber will respond to the tests for proteins.

If we wish to know why wool is warm, we must examine the physical arrangement of the wool cells. When wool fibers are examined under a high-power microscope, it will be noted that each fiber is covered by overlapping scales, as shown in the diagram on page 249. These scales, together with the curled nature of the fibers, give wool its warmth, because this structure imprisons air. Air which is not in motion is one of the best insulating materials. The vast quantities of air which are entrapped under the scales and between the crinkles give wool its wonderful quality of retaining warmth.

Wool has other properties which make it a much-used fabric. The fibers are fine and soft, although these qualities vary with the breed and the health of the sheep from which the wool comes. Wool fibers of the best quality come from the shoulders and sides of the sheep. These fibers, as a rule, are fine in texture, whereas those coming from the chest and legs are short and coarse.

Wool possesses the property of absorbing moisture to a marked degree. This property of absorbing moisture readily is very important in clothing materials. The ability of any kind of fabric to absorb

Johns-Manville

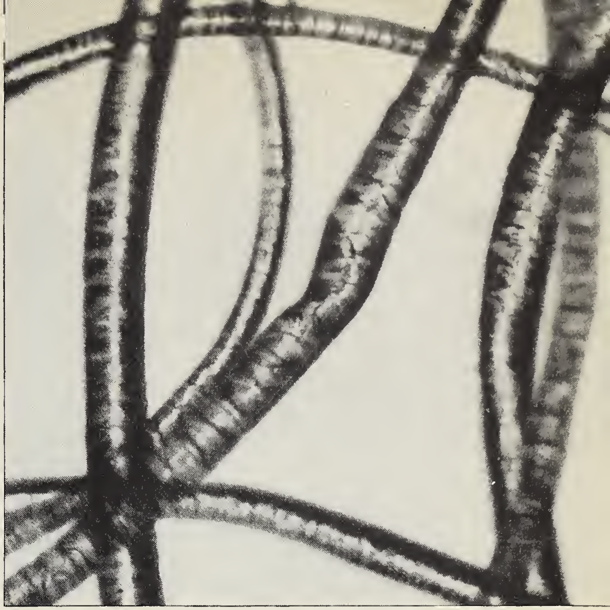
"The asbestos man." A complete suit of asbestos clothing is used by many fire-fighters, especially in the oil fields

water is technically known as its hygroscopic property. All fabrics possess some hygroscopic power.

A single wool fiber may be from 1 to 10 inches in length and may vary in thickness from $\frac{1}{3000}$ to $\frac{1}{500}$ inch. Those fibers which are from 8 to 10 inches long and from $\frac{1}{3000}$ to $\frac{1}{2000}$ inch thick are the most desirable ones from which to weave cloth.

The Associated Wool Industries list the following general characteristics of wool as the reasons for its being prized as clothing material: (1) It is a natural body covering. (2) It is thermostatic; that is, it protects from both heat and cold. (3) It is porous and absorbent, allowing the skin to breathe and absorbing perspiration. (4) It is fire-resistant in that it does not flare up easily. (5) It is elastic, and therefore clothing made from it holds its shape. (6) It is strong, durable, light, and soft.

Silk, the fiber of kings. Most silk is obtained from the cocoons of a particular type of silkworm known as the mulberry silkworm. There are many other silkworms which produce cocoons of silk, but they are not cultivated as the mulberry silkworms are. Silk produced by the uncultivated worms is known as wild silk or tussah silk.



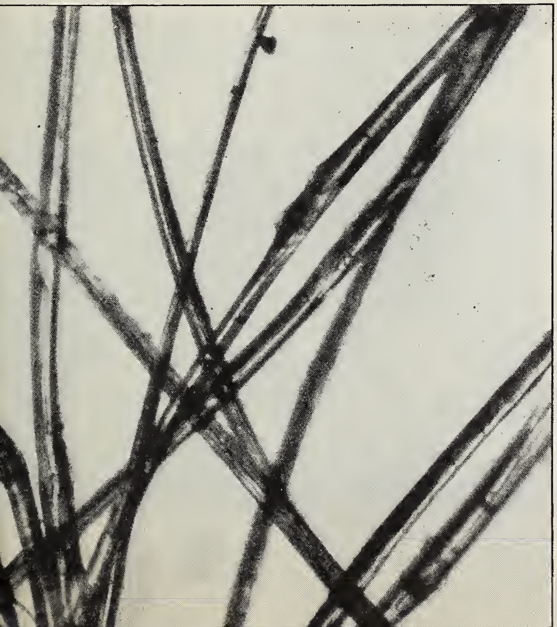
A. J. Iorio

Single wool fibers as they appear under the microscope

The silk fiber is formed by the silkworm to cover itself so that it can go through the pupa stage. The fiber is really made up of two different substances, known as fibroin and sericin. The fibroin is secreted by two glands in the upper part of the body and comes out through a tiny opening in the head. But just before it emerges, the sericin is secreted into the same exit tube and cements the two fibroin filaments together into a single thread. The fibroin coagulates, or hardens, just as it comes in contact with the air, and, when we find it, it is covered with the coating of sericin.

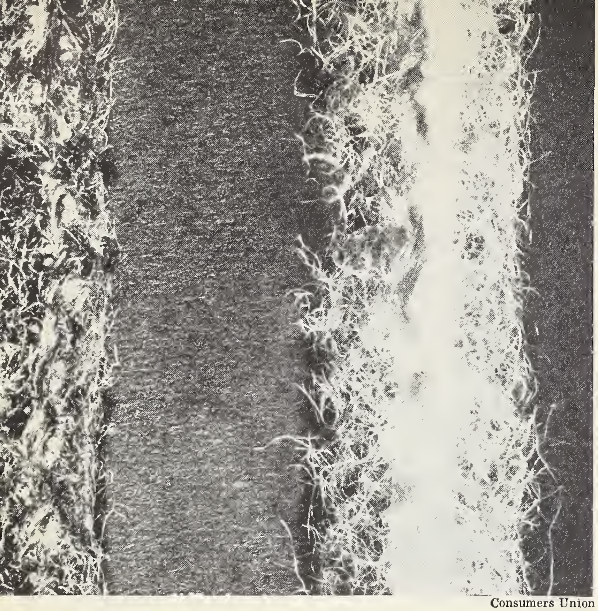
Silk fibers (highly magnified)

A. J. Iorio



Both fibroin and sericin are proteins and contain the elements oxygen, hydrogen, carbon, and nitrogen. They have been analyzed and found to contain nine different amino acids. Sericin is a gumlike substance which is soluble in hot water and is generally removed, by boiling, in some stage of the processing of silk for clothing.

Under the microscope the silk fibers look as shown at the left. The silk fiber is one of the finest fibers obtainable and also the longest natural one. The diameter of a single fiber may be from $\frac{5}{10,000}$ to $\frac{7}{10,000}$ inch, and its length may be from 1000 to 1400 yards. It is extremely lustrous, unusually strong, and elastic. A fiber of silk is as strong as a steel wire of the same diameter. Silk, like wool, is hygroscopic and, under certain conditions, will absorb as much as 30 per cent of its own weight without feeling wet. Boiled-off silk is not as hygroscopic as raw silk. Silk fibers will take most dyes



Consumers Union

The warmth of a blanket is mainly in the nap. The meager nap of the part-wool blanket on the left will not hold much warmth, nor will the blanket last long. The thick-napped all-wool blanket on the right is much warmer and will last much longer

readily, and this quality, plus their inherent luster, makes silk the most beautiful of fabrics.

Almost all our silk is imported because the cost of American labor is so high as to render its production here unprofitable, since many hand processes are necessary in its fabrication.

Silk has been used since 2700 B.C., or nearly five thousand years. At that time the empress of China, Si Ling, promoted its culture throughout all China. However, the source of the beautiful silk fibers was kept secret for many centuries. History tells us that two monks, in 555 A.D., finally succeeded in carrying some silkworm eggs to Europe in their hollow bamboo walking canes. But the industry still thrives best in Japan and China, and before the second World War it was mostly from these countries that we imported our silk.

Before the second World War, America consumed 80 per cent of the world's silk. We imported more than $100,000,000 worth of it annually.

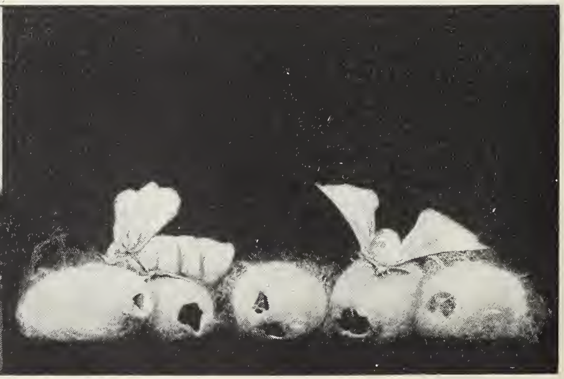
Furs and leather. The furs and skins of animals have long been used for clothing. These materials were easiest for early man to sew into large pieces, and most of his clothing needs were satisfactorily met by the use of furs and skins.

Furs and skins have approximately the same chemical composition as wool; that is, they contain the elements carbon, hydrogen, oxygen, nitrogen, sulfur, and some minerals which provide pigment for color.

Furs, as we use them for clothing, are the hair-covered skins of animals. There are two kinds of hairs on any hair-covered animal. First, there are the long, heavy, and shining hairs, known as guard hairs. Second, there are the short underhairs, called hair fibers or fur fibers. Each type of hair serves a special purpose for the animal. The guard hairs protect the finer, shorter fur fibers, preventing matting and causing water to be shed off the body.

A full-grown silkworm. It has finished feeding and is searching for something upon which to attach the first outer layers of its cocoon

Certain moths are allowed to hatch from the cocoons in order to perpetuate their kind. The cocoons broken open by the emerging adult are unfit for reeling, but have other uses



© Corticelli Silk Company

Underwood & Underwood

One operation in the processing of furs. These men are scraping a thin layer of flesh from the hide

The hair fibers prevent the loss of body heat and thus keep the animal warm in severe weather. Most animals lose both kinds of hair during the warm summer months and regrow new hair in the fall, when it begins to get cold. Under the microscope a fur hair shows the same scaly appearance as wool, but the central core, or medulla, is visible because of its pigment.

Furs are warm because a large amount of air is trapped between the tufts of hair and under the scales of each hair. The length of fur hairs and the general condition of fur depend upon the following: (1) diet and food supply of the animal; (2) temperature of the climate in which the animal grew; (3) whether the animal was trapped before or after hibernation; (4) amount and temperature of the water if the animal lives in water.

Leather is the processed, or tanned, skin of an animal from which the hair has been removed. Leather is a useful kind of clothing material because it serves a variety of purposes. It is ideal to protect our feet from wetness, injury, and cold. Leather is also the best material yet discovered for covering the hands. It is valuable for jackets, vests, and coats because it wears well and is warm. Many miscellaneous articles are made from leather. For example, key cases, hatbands, handbags, suitcases, and purses are necessary clothing accessories which are better when made from leather than from any other substance. Leather clothing is warm, largely because it prevents the entrance of air and hence retains body heat.

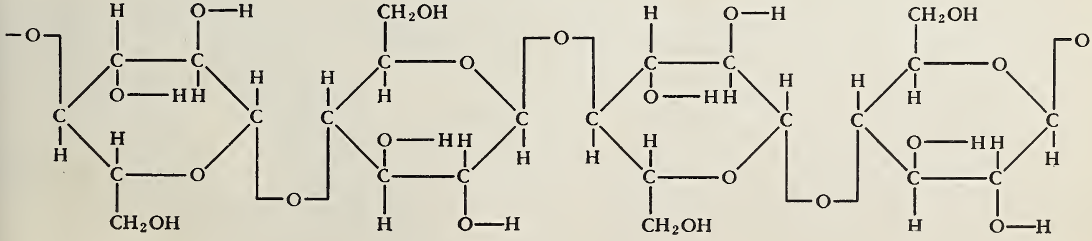
Fabrics made from vegetable fibers. *Cotton.* Cotton is the most widely used plant fiber in the making of clothing. This fiber may be woven into beautiful party gowns, or it may be used to make ordinary house dresses. Fancy dress shirts are made of cotton; so also are cheap work clothes.

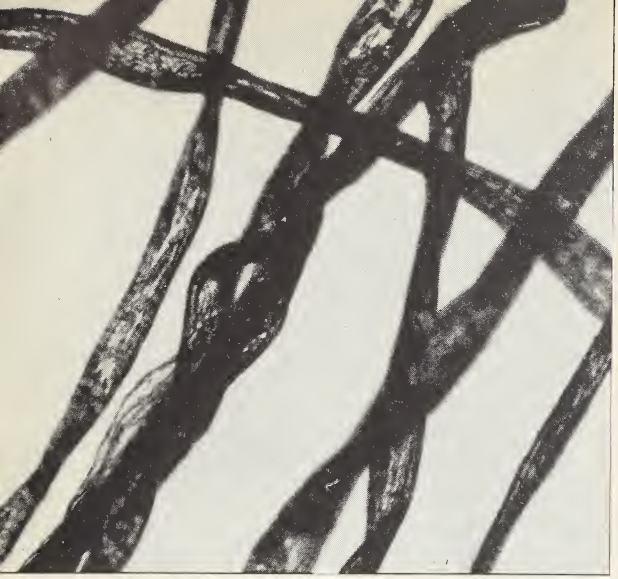
Cotton fibers are the hairs which grow about the seeds of the cotton plant. Chemists know the substance as cellulose, which has the empirical formula $(C_6H_{10}O_5)_x$. It is a carbohydrate and belongs to the same family as the sugars and starches. Its structural formula has been proposed as shown below.

This formula may be highly unintelligible to you, and certainly it is not expected that you memorize it; but it does show that the substance, cellulose, is not a simple material and that it is a carbohydrate.

The cotton fibers vary in length, or staple, as it is known in the textile trade, from $\frac{3}{4}$ inch to $1\frac{1}{2}$ inches for American cotton and from 2 to 3 inches for that grown in Egypt. Cotton fibers are as fine as the finest wool but not as fine as the best silk fibers. Each cotton fiber is a single cell. Before the fiber ripens, it is cylindrical. But after it ripens and dries, it flattens into an irregular twisted ribbon. Under the microscope the dry fibers look as shown in the picture on page 252.

Structural formula for cotton





A. J. Iorio

Cotton fibers (highly magnified). How do they differ from those of silk and wool?

Cotton fibers, because of their natural twist, are easy to spin and are very durable. They absorb water well but not as well as wool or silk. The fibers are not damaged by hot water, and therefore cotton fabrics may be washed and sterilized repeatedly. Cotton fibers are not elastic, which causes cotton fabrics to crush easily. Cotton fabrics also soil readily. These latter qualities detract from the usefulness of cotton. However, cotton is still the king of fabrics, and the world output is greater than that of any other fiber. The United States produces two thirds of the total world crop of twenty million bales per year.

Mercerized cotton. John Mercer, an Englishman, discovered that cotton would withstand the action of strong alkalies and be strengthened by it. However, the reaction must be carefully controlled. If the cotton fibers are immersed under tension in cold concentrated sodium hydroxide, they will be found to be smoother after washing and possess a luster similar to that of silk. Cotton treated in this manner is known as mercerized cotton. It is a desirable fiber for making stockings and underwear. A mixture of mercerized cotton and rayon also makes a fine fabric.

Linen, the summer fiber. Linen fiber comes from the inner bark of the stalks of the flax plant and, like cotton, is practically pure cellulose. The fiber is long, lustrous, absorbent, and smooth. The length averages 18 inches. It is very inelastic and difficult to dye. These qualities limit its use, but, for some purposes, it is unsurpassed as a fabric. Linen fibers are stronger and harder than those of cotton but less elastic. It is a better conductor of heat and therefore feels cooler to the touch than cotton.

Under the microscope the fibers have the appearance of bamboo canes with jointed cells and split tapered ends, as shown below. Linen fibers appear translucent; cotton fibers appear opaque.

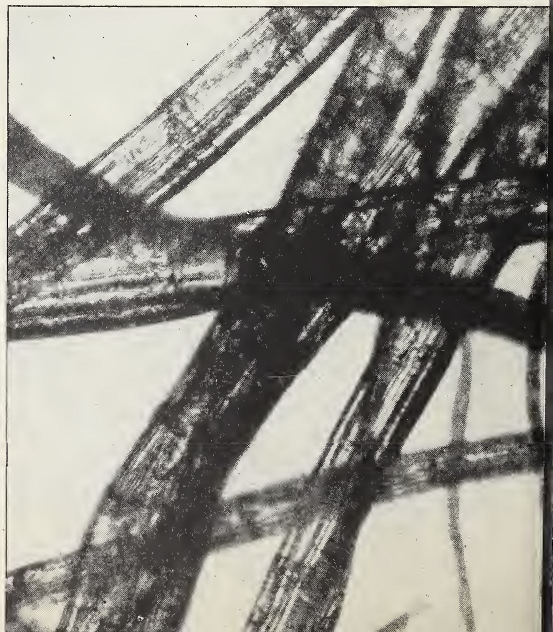
Practically all the linen used in the United States is imported because the flax plant is a temperamental one. It requires a moist climate where fogs and heavy dews are common and heavy rains are few. Ireland, Scotland, Belgium, and France produce the bulk of all the raw linen of the world.

Linen is an ideal fabric for making handkerchiefs, tablecloths, napkins, summer underwear, summer dresses, and shirts.

Jute, ramie, and hemp. Jute and hemp are plant fibers which come from plants related to the flax family. Jute and hemp are composed of a substance known as lignocellulose (a woody, simple cellulose). Chemically, they differ from linen and cotton, and the fibers are not fine enough for most clothing purposes. However, these fibers are used extensively for the making of carpets, twine, and sacks. Ramie,

Linen fibers as they appear under the microscope

A. J. Iorio



E. I. Du Pont de Nemours & Co.

Bales of raw cotton linters composed of short, raw cotton fibers which were left on the bolls after the larger fibers were removed. These constitute the principal raw materials used in the manufacture of rayon

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Loading a steeping press with sheets made of cotton linters and wood pulp, the first chemical step in the manufacture of rayon

or China grass, is the fiber of a plant belonging to the nettles. It makes a very good fiber for clothing because it is strong, durable, lustrous, and less harsh than linen. It is not used as widely as cotton or linen because, in separating the fiber from the cementing plant tissue, much hand labor is necessary. This makes the fiber costly. It is used mainly for the making of mantles for incandescent lamps, but some table linens are made from ramie.

Fabrics made from artificial fibers. *Rayon, the fiber of the mechanical silkworm.* Rayon is known as the man-made miracle fiber. It was discovered in 1884 by a Frenchman, Chardonnet, a student of Pasteur. He received his first information about cellulose in helping Pasteur to investigate the silkworm disease and, no doubt, got the inspiration to imitate the silkworm from this experience.

Rayon is made from cellulose. Fundamentally the silkworm and man start with the same basic substance, cellulose, in the making of silk and rayon fibers. The silkworm eats the cellulose and other materials of the mulberry leaf, digests it, changes it, and forces it through a tiny opening in its head, where it solidifies on contact with the air and be-

A close-up showing the unloading of cellulose xanthate from a baratte. How is cellulose xanthate made?

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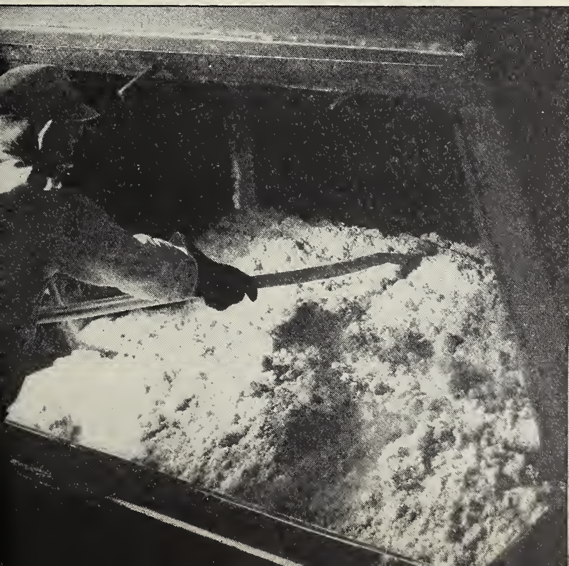

Liquid viscose transformed in a chemical bath into cellulose filaments to make rayon thread. Note the liquid being forced through the many fine holes in the spinneret and, in a short space, becoming separate rayon filaments, which, farther on, form a rayon thread

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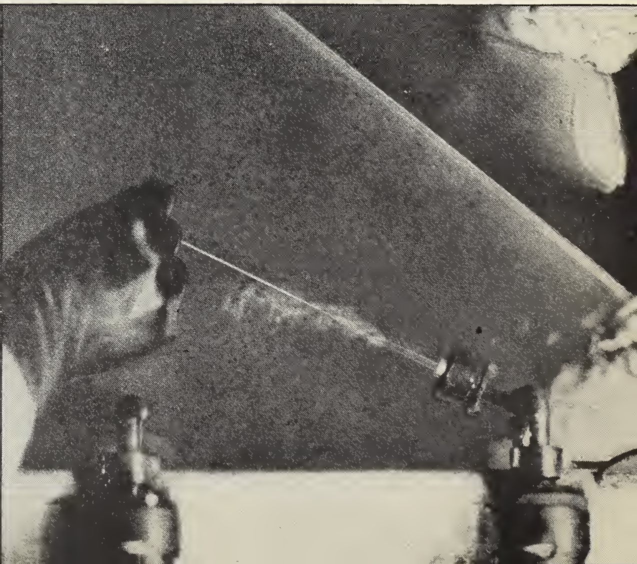

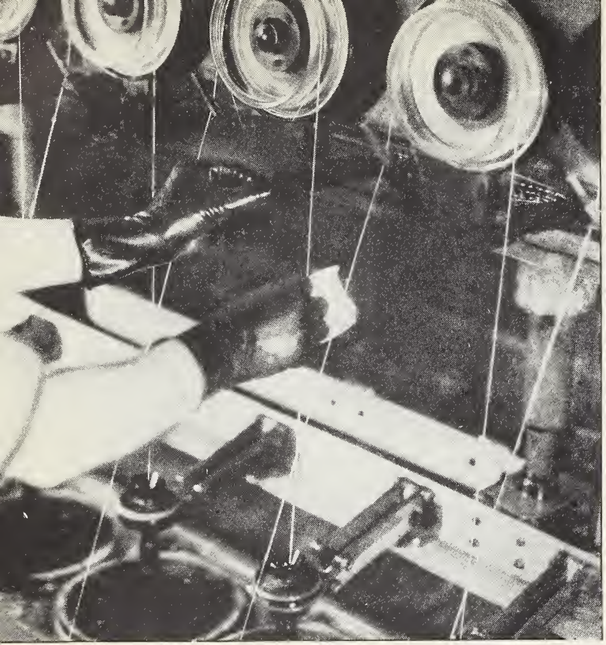

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"Threading up" a spinning machine for the making of rayon thread. When the spinning of a rayon thread is interrupted in order to remove the product periodically from the spinning bucket or to make some correction on the machine, production is resumed by using a stream of water from the cup in the operator's hand to lead the thread through the funnel guide into the spinning bucket. This requires considerable skill and is one reason for the many months of training necessary to make a competent spinning-machine operator

comes a strand of silk. Man takes cellulose from the wood of trees or from cotton and, by various chemical processes, converts it into a viscous substance which can be forced through tiny holes, thus producing rayon. However, rayon differs chemically and physically from silk. Though rayon is not as strong or durable or as fine in texture as silk, it is still a wonderfully useful fiber and is truly a man-made miracle.

The chemical production of rayon has increased the world's supply of textile fibers tremendously. In a recent year over one billion pounds of rayon was produced throughout the world. The United States ranks first in its production. Rayon has been found to be such a useful fabric and takes dye so well that it can be mixed with every other fiber to make clothing materials.

There are several kinds of rayon, with widely differing properties, due to variations in the process of manufacturing and the methods of weaving. However, all rayon has certain general characteristics which we should know.

Disadvantages of rayon. The best-known disadvantage of rayon, which has limited its use in the hosiery field, is its inelasticity. Lack of elasticity is partially overcome by different kinds of weaving. However, when rayon is knitted, it remains inelastic. Another poor characteristic that rayon possesses is loss of strength when wet. This quality is common to all rayons and is most important to the consumer in the case of articles which need to be laundered frequently.

Advantages of rayon. Rayon filaments may be made in any size, varying from fibers that are twice as fine as silk to those that are four times as coarse. This makes possible the weaving of a multitude of different fabrics. Then rayon can be made into cloth that has all variations of luster by adding certain pigments to the solution before the filament is spun. This is not possible in any other textile material.

Since the fiber is perfectly smooth, the fabric which is made from it is also very smooth and resistant to soiling. This property accounts for its universal use as coat-lining material.

Rayon fabrics do not mildew easily, and the white rayons remain perfectly white even after repeated washing.

Rayon, like all the other fibers, may be spun if it is first cut into short fragments. The yarn thus produced is called spun rayon. Textiles made from spun rayon can be made into materials which are difficult to distinguish from cotton, wool, silk, or linen.

Under the microscope rayon fibers look like transparent cylinders, as shown on the next page.

"*Nylon.*" Rayon has never matched silk in elasticity and strength, particularly when wet. Therefore chemists have been constantly seeking a fiber which could be artificially made and yet be the equal of silk. Such a fiber, known as "Nylon," has been developed. A $10,000,000 factory to produce "Nylon" has recently been completed. Hosiery and many other necessary articles made from this material are now on the market.

"Nylon" is made from substances known as diamines and dibasic acids, which can be synthet-

A. J. Iorio

Highly magnified rayon fibers

ically produced from the common raw materials coal, water, and air.

The chemical structure of "Nylon" is not identical with that of natural silk but is similar to it. It is said to be even more elastic and of finer texture than silk. It is used especially in the making of hosiery—where rayon has failed because of its inelasticity.

Hosiery made from "Nylon" possesses extreme sheerness, high elasticity, and strength. Hairbrush and toothbrush bristles and parachutes are now being made of "Nylon."

"Vinyon," another synthetic fiber. Another company is getting ready to manufacture a silklike fiber to be called "Vinyon." The raw materials for this material are coal, water, and limestone. The first product is acetylene (C_2H_2). A number of molecules of acetylene are combined by a process called polymerization to make large molecules of "Vinyon."

Lanital (synthetic wool) and other synthetic fibers. Lanital fibers are made largely from the casein of milk. Lanital has much the same chemical composition as natural wool, but the fibers lack the scales of natural wool, and consequently it cannot be woven into as warm a fabric. Preliminary tests indicate that lanital is not as durable as natural wool. However, technological improvements in its manufacture may overcome these deficiencies. In the future we may find that a lanital will be produced which will rival wool. Belgian chemists have produced a fiber very similar to lanital from the whey of milk. It is known as "Cargan." German chemists have made a new fiber which closely resembles cotton and is known as "Vistra." The processes of its manufacture are still secret.

Comparison of fibers. The table below presents a comparison of many properties of the five most common textile fibers. A rating of 1 indicates that the fiber and the fabrics made from it have that property to the greatest degree, while a rating of 5 indicates that the fiber and its fabrics have that property to the least degree.

Properties	Wool	Silk	Cotton	Rayon	Linen
Warmth	1	2	4	3	5
Hygroscopic property	1	2	4	5	3
Cost	3	1	5	4	2
Luster	4	2	5	1	3
Ability to take dyes	3	2	4	1	5
Elasticity	1	2	3	5	4
Length of fiber	4	2	5	1	3
Diameter of fiber (fineness)	5	2	3	1	4
Strength of fiber	4	1	3	5	2

EXERCISES

1. What clothing fabrics are obtained from animals?

2. Why is wool warm?

3. What chemical elements are found in animal fibers?

4. How does wool differ from silk in chemical composition?

5. What mineral substances are used in the manufacture of clothing?

6. How does wool vary in quality?

7. What are different kinds of silk?

8. Show by drawings the relative lengths and diameters of wool, cotton, and silk fibers.

9. What are the two protein materials found in silk?

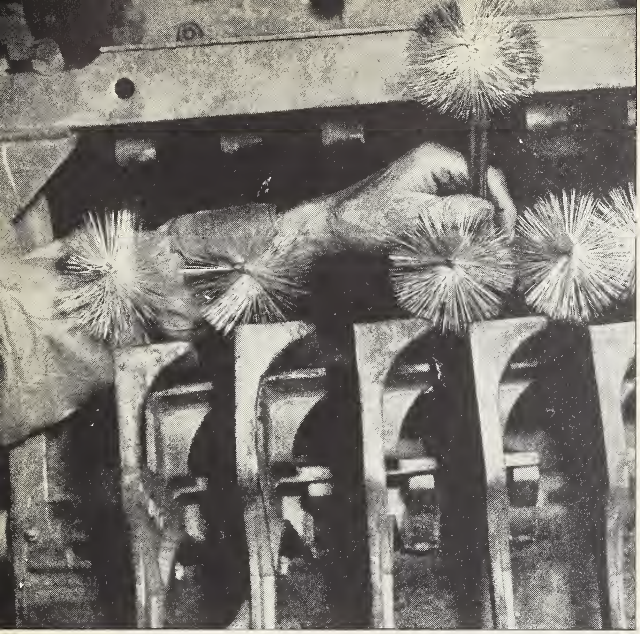
10. Duplicate the microscopic pictures of wool, silk, cotton, linen, and rayon fibers.

11. How does rayon differ from silk?

12. What are the essential differences in composition of rayon, "Nylon," and silk?

13. What are the differences in the properties of rayon, "Nylon," and silk?

14. What is the approximate composition of furs and skin?



E. I. Du Pont de Nemours & Co.

A scene in the plant of a large bottling company, where brushes with "Nylon" bristles are used for cleansing bottles. The operator is inserting new brushes into the machine. These bristles have unexcelled sanitary and lasting qualities. "Nylon" is derived basically from coal, air, and water

The sheerness of women's hosiery manufactured from "Nylon" yarn is demonstrated in this picture. Stockings made from this new material will dry extremely rapidly after laundering. The fibers are substantially as strong when wet as when dry. "Nylon," a protein-like material, is a recent development in the laboratories of E. I. Du Pont de Nemours & Co. This material gives textile fibers of unusual strength and elasticity

Ewing Galloway

E. I. Du Pont de Nemours & Co.

Scene from the Du Pont educational motion picture *A New World through Chemistry,* showing "Nylon" lace dress, "Lucite" costume jewelry, and rayon drapery

15. How long have we used silk as clothing material?

16. Do you believe that synthetic fibers will replace natural fibers for clothing materials? Why or why not?

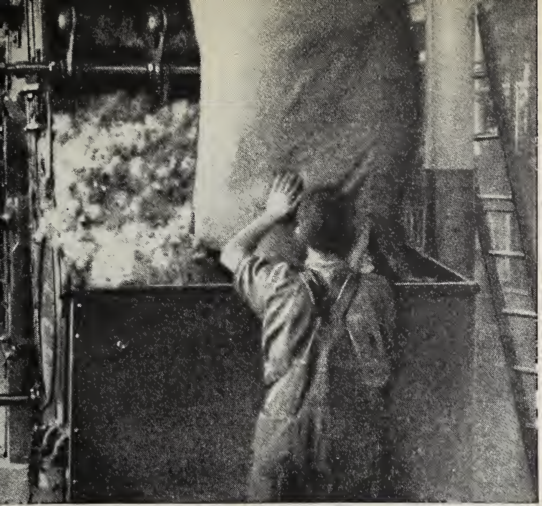
17. What is the chemical composition of cotton? of linen?

18. What are the good qualities of rayon? the poor qualities?

Problem 3. How are the different fabrics made?

Preparation of wool yarn. After the raw wool is clipped from sheep, it is first washed with soap, sodium carbonate, and potassium carbonate to remove the dirt and impurities. Strong caustic alkalies are not used, because they would dissolve the wool.

The foreign vegetable matter which still remains after this washing process must be removed by treating with hot dilute sulfuric acid at a temperature of about 150° F. This acid treatment causes the woody matter to become brittle and loosened sufficiently so that it can be removed by shaking the wool on mechanical shakers. The excess sulfuric acid is neutralized by adding some additional sodium carbonate to the rinse water. After additional washings, the wool is then white and ready to be carded.



© National Motion Picture Bureau

Emptying a bag of sorted wool into the washing machine

The carding leaves the wool hairs lying in one direction, so that they can be spun into yarn. The spinning is done mechanically by twisting two or more fibers. They adhere easily because of their scaly nature. The wool yarn is then ready for weaving. Countless kinds of woolen fabrics may be woven by varying the weaving process.

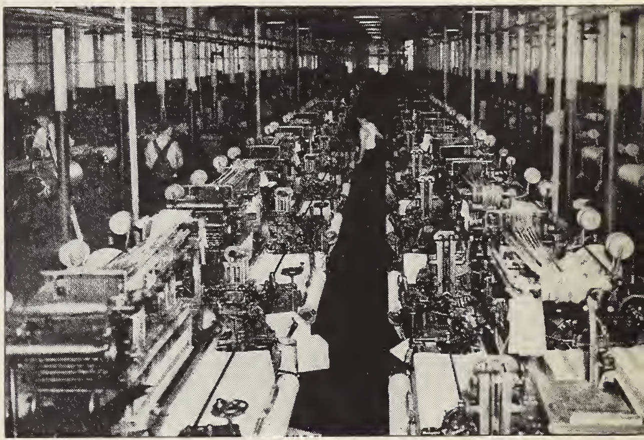
One of the important by-products of the preparatory treatment of wool for spinning is lanolin, or wool grease. Lanolin contains cholesterol, an ingredient that is easily absorbed by the skin and therefore is widely used in face creams and skin ointments.

The preparation of silk for weaving. The silk cocoon is placed in boiling water and then in cold water to soften the gum surrounding the fibers. The strands of the continuous fiber are then ready for reeling. This is done by combining from two to twenty strands from as many cocoons into a single thread. The silk thus produced is known as raw silk and is wound in skeins, or hanks. Before silk threads can be woven, they must go through a series of washings and "weightings." Raw silk contains about 75 per cent of pure silk fiber and 25 per cent of silk gum, or sericin. The sericin is removed by cooking the raw silk in hot soap solution. The silk is then known as degummed silk or boiled-off silk. The amount of gum which is removed determines the kind of silk.

For the making of fabrics it is not desirable that the silk be completely boiled off, as it is much less hygroscopic in that form. Good silk fabric will

Cheney Brothers

Opening a bale of raw silk after its arrival in America

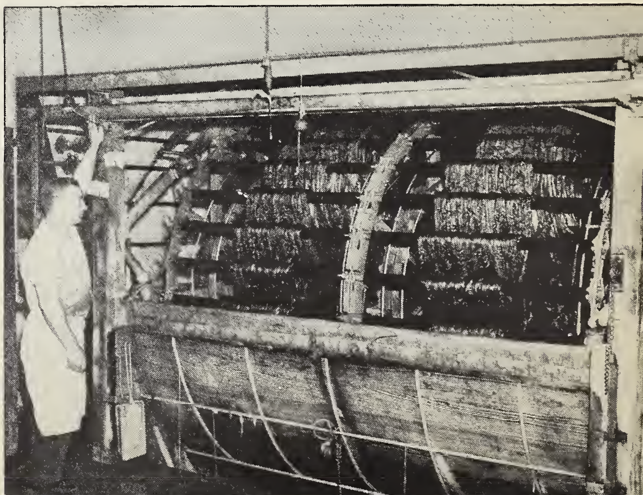


Cheney Brothers

Interior of a silk-weaving mill in America

The dyeing of silk skeins

Cheney Brothers



absorb water up to 30 per cent of its weight and still not feel wet to the touch.

Most silk which is called pure silk is really not pure silk, for practically all silk is weighted with mineral substances. The weighting is usually done during the final finishing and dyeing processes. Weighting is accomplished by soaking the silk in a solution of metallic salts. Iron tannate (the substance used in making some inks) is used where dark-colored fabrics are desired. A double insoluble salt, tin silicophosphate, is used where white or light-colored silk fabric is wanted. The weighting substances are absorbed by the fabric because they become imprisoned within the fibers and, being insoluble, stay there through repeated washings or cleanings. The compounds used in weighting also assist in "fixing" the dye into the cloth and therefore make the colors "fast."

An amount of weighting equal to the amount of sericin lost in the boiling-off process is considered desirable, and such silk is sold as pure-dye silk or pure silk.

As with other fabrics, different kinds of silks may be produced by varying the weaving process. For example, satin, one of the most beautiful weaves adaptable to silk, is made by crossing each lengthwise thread with several crosswise threads. This produces a fairly long stretch of yarn which lies unbroken on the surface. The smooth surface reflects light and gives satin its beautiful glossy appearance. The possibilities of fabrics made from silk are almost limitless.

How are furs prepared for use? Fur-bearing animals inhabit wild country and are found on land and in rivers, lakes, and swamps. Most of them are caught by traps. However, the demand for furs for clothing has become so great that many people have established large fur farms. Here the animals are raised scientifically, being provided with the best food and care so that their fur will be of excellent quality. Getting the animal constitutes the first step in obtaining the processed fur. After being killed, the animal is skinned so that the pelt is removed in one piece. Then the pelt is stretched and dried, fat and flesh are removed, and from some furs the longer, unsightly guard hairs are removed by plucking. The pelts must next be tamped until soft and the excess fat removed by putting the pelts in drums with sawdust. The skin must then be tanned to keep it from rotting or deteriorating. The tanning substance consists of (1) chromium alum salts, (2) mineral and vegetable oils, or (3) salts and acid mixtures. One of these mixtures is brushed or tamped into the skin in order to preserve and tan it. After being dried under controlled conditions, the fur is then ready to be dyed or bleached. The same principles are applied in dyeing furs as in dyeing clothing. Since natural oils are removed in dyeing, which weakens the fur, dyed furs do not last as long as undyed ones. Furs are bleached with sulfur dioxide (SO_2) or hydrogen peroxide (H_2O_2). The furs are now ready to be sewed together to make the larger pieces necessary for coats.

What chemical processes are involved in the treating of skins to make them into leather?

How is leather tanned? Leather is the tanned skin of any animal. The skin of some animals, such as cattle, makes more durable leather than that obtained from other animals, such as sheep.

In the tanning industry the word *hide* is used in referring to the pelt of a large animal, such as a cow or a horse, and the word *skin* in referring to the pelt of a small animal, such as a sheep or a goat. The terms *cowhide* and *sheepskin* are used for the leathers made from the cow and the sheep.

If hides or skins are left exposed to the oxygen and germs of the air, they will soon decay and thus be useless to man. Therefore he puts them through a process which hardens and preserves the fibers. This is known as tanning. The materials which a tanner uses are (1) the barks of various trees, such as oak, willow, and hemlock, which contain the chemical substance tannin, or tannic acid ($C_{76}H_{52}O_{46}$); (2) the leaves, fruit, or extracts of such shrubs as sumac and palmetto, which also contain tannic acid; (3) chemical substances such as lactic acid ($CH_3 \cdot CH(OH) \cdot COOH$), the acid of sour milk; casein, a protein material also found in milk; blood albumin; sulfuric acid; potassium hydroxide; sodium hydroxide; potassium dichromate ($K_2Cr_2O_7$); (4) oils and waxes, such as neat's-foot oil (oil obtained by boiling the hoofs of certain cattle) and paraffin.

The raw hides must first be dehaired. This is accomplished by soaking the hides in solutions of lime ($Ca(OH)_2$) or sodium sulfide (Na_2S). These substances are known as depilatories, and the process is sometimes called depilation. The hair follicles are so softened by this soaking process that they can easily be scraped off with a blunt knife. The hides, which have absorbed much calcium hydroxide in the dehairing process, must then be placed in a weak acid solution to neutralize the base before a tan can be applied. After this treatment the hides are placed in a solution containing an enzyme, obtained from the pancreas of animals, which attacks the cementing material between the fibers and removes it. In early methods this latter process, known as batting, was done by burying the hides in dog or hen manure. The hides must next be "pickled" in salt and sulfuric acid solution to strengthen them. After "pickling," they may be either stored or tanned. If the hides are to be immediately tanned, they go into a bark liquor made by letting hot water trickle through the finely ground bark of trees, or they go into a chrome liquor made by mixing potassium dichromate, water, sulfuric acid, baking soda, and glucose in lead tanks. Leather tanned by the bark method requires from 150 to 180 days for the completion of the process, while the chrome method takes only one day. In vegetable-tanned leather the chemistry of the final tanning process is not fully understood, but it is known that 60 parts of tannin should unite with 100 parts of the underskin (collagen) to form leather. In chrome tanning, the salt, basic chromium sulfate ($CrOHSO_4$), combines with the collagen to form leather.

The tanned leather is pressed to remove water. It is then trimmed and soaked with neat's-foot oil or castor oil to finish it and give it "life," or flexibility. Before this last process it may be dyed a desired color.

Finishing leather. The final finish which is applied to leather varies with the use to which it is to be put. The leather may be hand-finished by rubbing into it a mucilage made from flaxseed or by applying blood albumen. Grain effects or designs may be embossed upon it by pressing it in powerful machines. Thus split cow leather may be made to look like pigskin or like alligator skin. Patent leather is leather to which has been applied a nitrocellulose lacquer. Ordinary grain in leather is obtained by rubbing it with large cork boards.

Every big tannery has a chemical laboratory with several trained chemists who constantly check the many chemical reactions in the tanning process and devise new methods of tanning.

How are cotton fibers prepared for weaving? Cotton contains impurities, as do other raw textile materials, and these must be removed before weaving. Raw cotton contains about 90 per cent pure cellulose, while the rest is water, gum, cotton wax, and mineral matter. Boiling the spun cotton threads in a 1 per cent solution of sodium hydroxide removes the wax by emulsifying it. Further treatment of the boiled-off cotton with diluted acid, water, and alcohol removes all the impurities, and chemically pure cellulose is obtained. The threads may be woven when the cotton is in the boiled-off stage or when it is in the pure cellulose form. The woven cloth may be bleached with chloride of lime ($CaOCl_2$) to whiten the fabric. Most housewives prefer white cotton goods, even though bleaching weakens the cloth.

An important factor in obtaining good-quality cotton cloth is that of the length of fiber used in the spinning of the thread before any of the above processes are applied. The long-fiber cotton is "combed," and the short-fiber cotton is "carded" before spinning. Combing completely straightens out the fibers, while carding only partially lays them parallel. Yarn spun from long-fiber "combed" cotton is smoother and produces a thread of smaller diameter with a harder finish than does that made from short-fiber "carded" cotton.

Ewing Galloway

Picking a fine crop of cotton

Again, the type of weaving of cotton produces a wide variety of cotton goods. Novelty weaves and twills of all descriptions may be produced by adding supplementary threads, by loose or tight weaving, and by using tightly or loosely twisted yarn.

The making of rayon. There are four different processes by which rayon is made. Three of these processes are known as regenerative processes because the cellulose solution is regenerated into the pure cellulose state. The names of these three processes are those of the substances used in getting the raw cellulose into solution. They are (1) nitrocellulose, (2) cuprammonium, and (3) viscose.

The fourth process is known as the acetate process and is nonregenerative, because the cellulose is not regenerated into pure cellulose. In this form the physical structure and the chemical structure of the cellulose are changed, and the properties of the rayon are different from those of the regenerated forms. Such rayon is given the name *acetate rayon.* It is important that you be able to tell the difference between acetate rayon and the other forms of rayon.

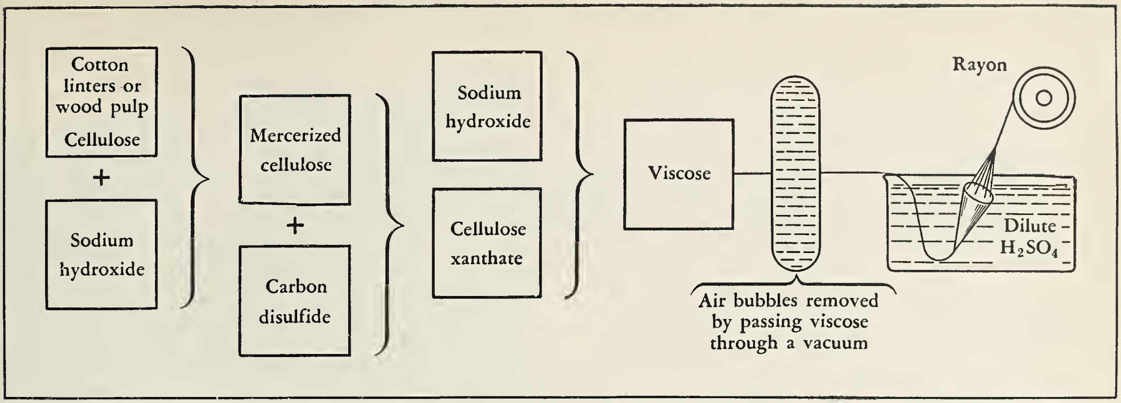
Rayon from guncotton. The first process of manufacturing rayon, the nitrocellulose process, was discovered by Chardonnet. No rayon is made in America by this process, because cheaper methods are now available. When this method is employed, the pure cellulose fiber is first converted into nitrocellulose by heating it with a mixture of nitric (HNO_3) and sulfuric (H_2SO_4) acids. The nitrocellulose (guncotton) is then dissolved in a mixture of alcohol and ether. This solution is similar to collodion and, in this form, is ready to be made into fine threads. To obtain the fine filaments, the solution is forced through dies containing tiny holes, which are about $\frac{2}{1000}$ inch in diameter, into warm water or air. The solvent readily evaporates, leaving nitrocellulose fibers. Since nitrocellulose is very inflammable, it must be denitrated. This is accomplished by treating the nitrocellulose with ammonium sulfide ($(NH_4)_2S$), and consequently pure regenerated cellulose strands, or filaments, are obtained. After repeated washings and dryings, the small fibers are ready for spinning and weaving. The high cost of the solvent makes this method of manufacturing rayon a costly one.

The viscose method. More than 85 per cent of the rayon manufactured today is made by the viscose method. It is called viscose because the fluid which is to be made into fine threads is viscous, or sirupy.

The source of the rayon may be wood pulp or cotton linters. Cotton linters are the short fibers of cotton which adhere to the seeds. The purified cellulose is put into solution by first treating it with sodium hydroxide, aging it for four days under controlled temperature, and then mixing it with car-

This carding machine performs the first of many processes which straighten the long fibers of cotton and eliminate the shorter fibers. The laps of cotton, about 39 inches wide, are put through the carding machine, where thousands of small wire hooks, revolving on a cylinder, card the wool. Each lap is drawn into a thin layer, which is formed into a light rope of cotton, known as a "sliver." The slivers pass from the machine and are wound spirally into a deep metal pail

Underwood & Underwood



The viscose process of making rayon

bon disulfide (CS_2). This mixture is known as cellulose xanthate and, after further aging, is mixed with more sodium hydroxide. The resulting solution has all the air bubbles removed by passing it through a vacuum; it is then ready to be forced through dies containing hundreds of tiny holes into a saturated solution of ammonium sulfate or chloride. This solution precipitates the viscose filaments. Further heat treatment regenerates the cellulose, and the filaments are twisted into threads. The rayon is finally washed and bleached in skeins, whence it is wound upon spools ready for weaving.

The cuprammonium process. This process differs from the others in that a different solvent for the cellulose is used. Pure cellulose is dissolved in an ammoniacal solution of copper hydroxide. The cellulose solution is then forced through fine jets into an acetic acid bath, where the cellulose is precipitated into filaments. Rayon made by this method is of good quality, lustrous, and silklike in appearance. It is sometimes called Bemberg rayon.

The acetate process—"Celanese." Rayon, by this process, is made by combining the cellulose with acetic acid and acetic anhydride (dehydrated acetic acid). The product is cellulose acetate, and it retains this composition even when it is made into filaments. Such rayon is commonly called acetate rayon and is sold under such trade names as "Acele," "Celanese," and "Eastman Acetate."

From the consumers' point of view, it is very important to recognize the difference between acetate rayon and other kinds of rayon. Acetate rayon must be laundered and cleaned differently from other rayons. It may be easily distinguished by placing a few drops of acetone, liquid nail-polish remover, upon a thread or two. If the threads are acetate rayon, they will dissolve, but no other rayon or other fabric will be thus affected.

If properly cared for, acetate rayon is more durable than other forms of rayon and is particularly suitable for use as coat linings and other such uses.

EXERCISES

1. How is wool prepared for carding? What chemicals are used in the preparatory processes?

2. What is lanolin, and how is it obtained?

3. What differences can you mention between the way in which the silkworm makes silk from cellulose and the ways in which man makes artificial silk from cellulose?

4. What are the necessary steps in preparing the silk of the cocoon for the silk threads out of which cloth is made?

5. What is boiled-off silk?

6. Explain what the term *pure silk* means.

7. Describe how silk is weighted.

8. Show by a diagram or a sample of cloth how satin differs from plain-weave silk.

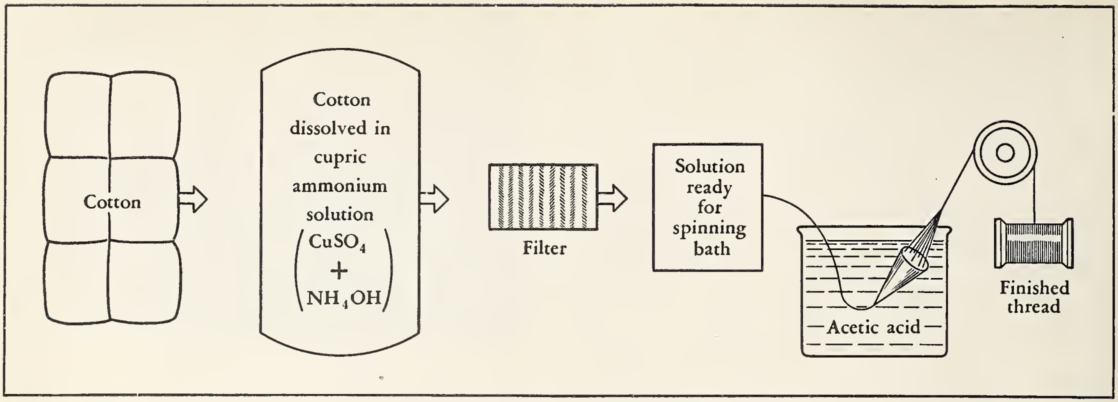
9. If you wished to prepare fur pelts for use as clothing, what would you do to them?

10. How are furs bleached?

11. What does the term *tanning leather* mean?

12. What is leather? Is it a chemical compound?

13. List the clothing materials which are made from hides; from skins.


Cotton
Cotton dissolved in cupric ammonium solution
$CuSO_4 + NH_4OH$
Filter
Solution ready for spinning bath
Acetic acid
Finished thread

A simplified flow sheet for making rayon by the cuprammonium process

14. What are the differences in making chrome-tanned leather and bark-tanned leather?

15. Inquire of a shoe-manufacturer or cobbler about the relative merits of chrome-tanned leather and bark-tanned leather. List your findings.

16. What is neat's-foot oil? How does it help to preserve leather?

17. What preliminary treatment is necessary before the cotton of the field is ready for weaving?

18. What are the differences between good-quality cotton and poor-quality cotton?

19. Explain the differences between carding and spinning.

20. How is cotton woven?

21. List and describe in a few sentences each of the four methods of making rayon.

22. Outline in detailed form the chemical steps necessary in making rayon by the viscose method; by the acetate method.

23. Is rayon the same in chemical composition as silk? Why or why not?

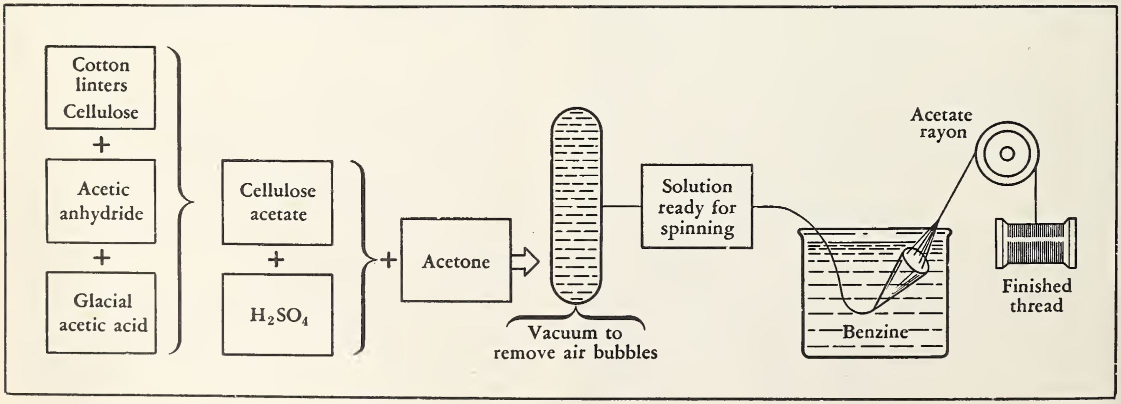
24. Explain what is meant when we say that to make rayon, we must first get cellulose into solution. Is cellulose soluble?

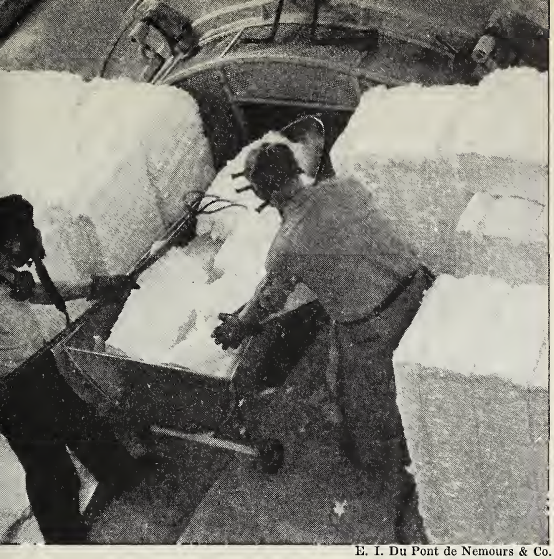
25. What is "Bemberg" rayon?

Problem 4. How are fabrics dyed?

Man seeks to capture the beauties of nature. The dyeing of materials is probably as old as civilization itself. At least, the earliest prehistoric remains show that man sought to impart color to his clothing and

A simplified flow sheet for making rayon by the acetate method





E. I. Du Pont de Nemours & Co.

View of an acetator which is being filled with cotton linters, a process in the manufacture of "Acele" acetate rayon. Cotton linters are treated with anhydrous acetic acid to reduce them to liquid form. What are cotton linters?

utensils. Perhaps he was attracted by the color of his surroundings, such as berries, flowers, fruits, and even the plumage of birds. He probably tried to transfer the juice of berries to his clothing in an effort to produce a decorative effect.

As he became more civilized, man discovered a number of natural dyes and became more efficient in the art of dyeing. Many dyes were rare, and only the wealthy were able to have clothing or robes of certain colors. The beautiful Tyrian purple was obtained from a liquid found in a tiny sac in the head of a certain Mediterranean shellfish. It was so rare that only the robes of the wealthy were dyed in this color. We read in the Bible of the colored robe of Joseph and of how his brothers envied him because of it. Man is continually seeking to transfer the colors of nature to his clothing and to the furnishings of his home.

Dyes are classified as natural and artificial, or synthetic. Natural dyes are those obtained from nature, though they may be purified by man. Synthetic dyes are manufactured and created by man.

Natural dyes. Until a few years ago, all dyes were obtained directly from nature. Some of the common natural dyes are indigo blue ($C_{16}H_{10}N_2O_2$), obtained from the indigo plant, grown principally in India; Turkey red, obtained from madder root; a black dye obtained from logwood; a brown dye from butternut hulls; and a scarlet dye obtained by grinding an insect called cochineal. The insect, cochineal, is found in Central America, and the dye is obtained by grinding millions of the insects and boiling them in water. As is the case with many natural dyes, this dye is an indicator and may be used in the identification of acids and bases.

Natural dyes are often dull in color and soon fade. The number of different tints which can be obtained is small.

Synthetic dyes. In 1856 a young English chemist by the name of William Perkin was working with coal tar in an effort to obtain quinine. He was surprised while experimenting by the appearance of a beautiful violet color. Thus began a new epoch in the production of color for our modern world.

It is really not so simple an operation as it may seem, to obtain beautiful dyes from coal. When coal is subjected to destructive distillation in the production of coal gas and coke, one of the by-products is coal tar. Destructive distillation is the process of heating some combustible substance to a high temperature in the absence of air. When materials such as coal or wood are thus heated, some of the complex organic compounds are broken down into simpler substances, and these, with the other volatile substances in the coal or wood, are driven off in the gaseous state. Some of the gaseous prod-

Analytical and dye-testing section of the technical laboratory of E. I. Du Pont de Nemours & Co. What qualifications do you think a chemist must have to work in such a laboratory?

ucts are used for fuel. Other gaseous products are condensed to the liquid state. Such products are known as by-products. The principal products, in the case of coal and wood, are coke and charcoal.

From coal tar are obtained such chemicals as naphthalene (moth balls), benzene, toluene, phenol, and anthracene. By a series of complicated chemical steps in which other atoms or radicals are added to the compounds named above, many beautifully colored dyes are produced.

Until the time of the first World War the German chemists produced most of the world's synthetic dyes. Since that time American chemists have been able to produce all the dyes that the Germans produced and many new ones.

The vast indigo industry of India was destroyed by the chemist, because indigo can now be produced from coal tar at 20 per cent of the original cost, and the product is more uniform. Alizarin ($C_{14}H_6O_2(OH)_2$), a fundamental red-yellow dye, which was produced from madder root, is now produced synthetically from anthracene.

Most of our dyes today are synthetic. These man-made dyes have the following advantages over natural dyes: (1) Synthetic dyes may be produced for about 20 per cent of the cost of natural dyes. (2) Synthetic dyes are more brilliant. (3) The colors of synthetic dyes are more "fast." They do not fade or run nearly as readily as the colors of natural dyes. (4) Many thousands of shades and even many new colors are now available from synthetic dyes. (5) Synthetic dyes are made under controlled conditions, are purer, and are uniform in quality.

What are the classes of dyes? Dyes may be classified according to their chemical action with the various textile fibers. Those dyestuffs which react directly with certain fibers, forming an insoluble colored compound, are called *direct* dyes. Other dyes do not react directly with the fibers but require the presence of a chemical assistant called a mordant in order to form an insoluble colored compound. These dyes are called *mordant* dyes. The mordant seems to be absorbed by the fibers and then reacts with the dye to form an insoluble substance which remains "fixed" to the fiber. A third class of dyes is produced in the fibers by the reaction of two substances, neither of which is a dye. This type of dye is called a *vat* dye.

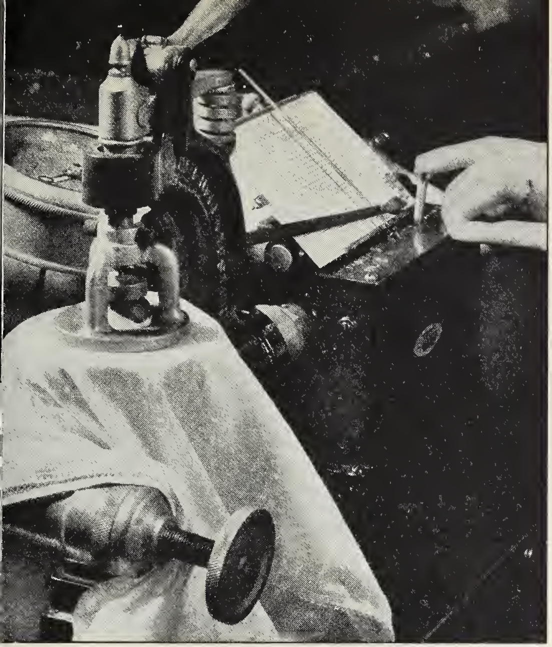
How are vegetable and animal fibers dyed? Cloth materials are dyed in several ways. Where a solid color or a simple combination of colors is desired, the hank, or yarn, is usually dyed before weaving. Woven cloth may be dyed by the piece, or the dye may be printed on one side or both sides. When yarn or thread is dyed first and cloth is woven from the dyed yarn, the name "hank or yarn dyed goods" is applied to the finished product. Sometimes the fabric is woven from bleached or unbleached fibers and then dyed, and is called "piece-dyed goods." Often material such as cretonne has the design printed on it after it is woven. These methods of dyeing are used for animal fibers as well as vegetable fibers.

Few dyes will adhere directly to cotton or linen; most require a mordant. The mordant is a substance which will usually hydrolyze (see page 114) to form an insoluble hydroxide in the fibers of the goods. The goods may be cotton, linen, silk, wool, rayon, or acetate rayon. The first step is usually to soak the yarn or fabric in a solution of a salt of chromium, aluminum, iron, tin, or copper. This solution thoroughly saturates and penetrates the fibers. Next, the material is soaked in a base, such as NH_4OH, which causes an insoluble hydroxide to be precipitated in the fibers. The reaction may be represented by the following equation when ferric sulfate is the mordant:

$$Fe_2(SO_4)_3 + 6\ NH_4OH \longrightarrow 3(NH_4)_2SO_4 + 2\ Fe(OH)_3\downarrow$$

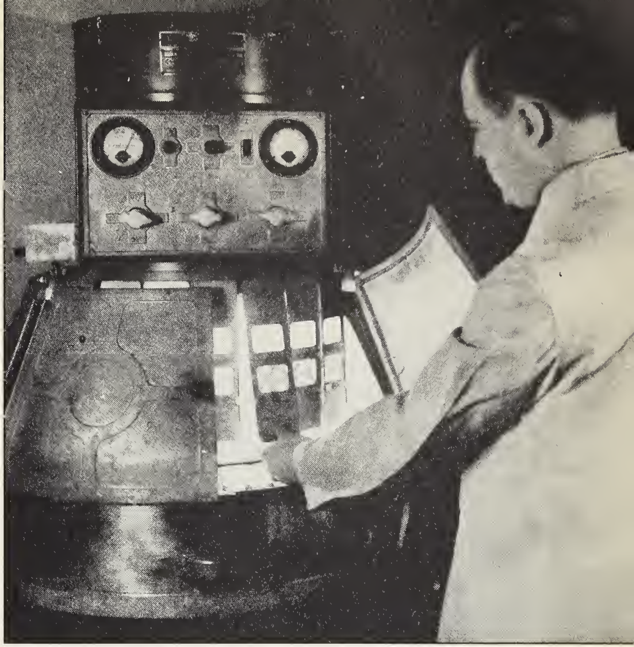
The goods are then dipped in the dye solution. The colloidal particles of dye adhere to and react with the insoluble hydroxide and become fixed to the goods. The combinations of the dye with the insoluble hydroxide form an insoluble "lake." Different colors are produced by using different mordants with dyes. Aluminum and tin salts produce the most brilliant colors, and copper and iron salts produce the most permanent colors. Variations in the shades of colors can be produced by the use of sulfur, tannic acid, and fatty acids. Wool and silk are more easily dyed than vegetable fibers. The color of vegetable fibers is more apt to run, or "bleed."

What are vat dyes? Vat dyes are those which are formed within the solution as the goods are being



Good Housekeeping Institute

This is a bursting-strength machine which is used to measure the strength of knitted fabrics and garments; thus their durability, or length of life, can be predicted



Good Housekeeping Institute

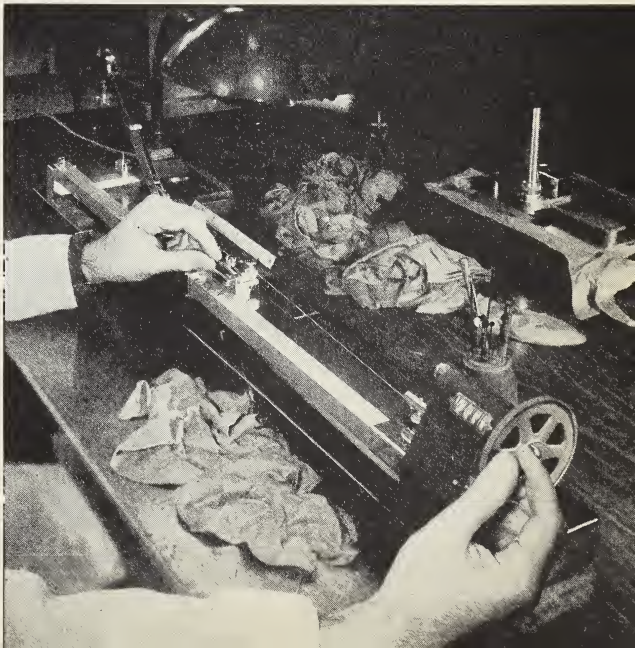
This "fade-ometer" is used to find out if fabric dyes are resistant to sunlight. It multiplies many times the fading action of sunlight

This is a tensile-strength machine; it is used to measure the strength of woven fabrics. One of its important uses is to find out the effect on fabric strength of various brands of laundry soap

Good Housekeeping Institute

Thread construction is analyzed by means of a "thread-twister." It counts the number of plies and twists, or turns per inch, in a thread. How does the number of plies and twists per inch affect the wearing qualities?

Good Housekeeping Institute



dyed. Soluble indigo is colorless. The goods to be dyed are soaked in an indigo solution. Oxygen of the air then oxidizes the soluble indigo to form an insoluble blue precipitate of indigo, which dyes the cloth. Vat dyes are fast; that is, they retain their original color through ordinary washing and wearing.

How are goods printed? Printing is usually done by blocks or rollers upon which the design has been produced in relief, or embossed, form. Usually a dye paste, which is a mixture of a mordant and a dye, is placed on the blocks or rollers and is applied to the goods by pressure. A dye paste is what dyers call a lake. In other cases, the goods are dipped in a mordant previous to printing. In still other processes the goods are dipped in a dye, and the figures are printed with a mordant. The goods are then washed thoroughly. The dye washes out of the goods not printed with the mordant.

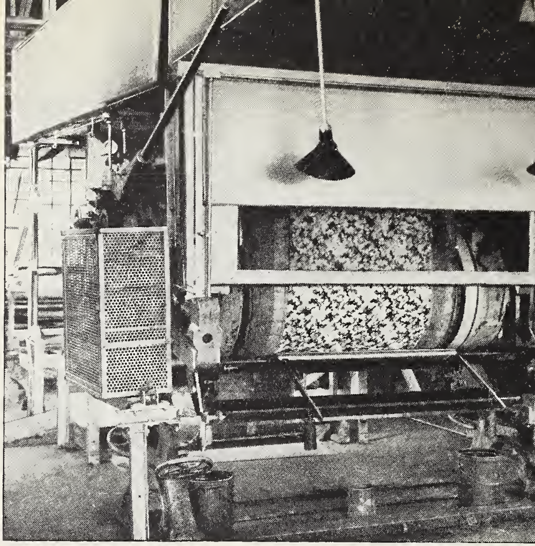
What qualities should a good dye possess? When you buy new materials or garments, you are attracted by the color and appearance of the goods. You will learn that you should be careful in the selection of goods as to quality of workmanship and as to the material of which they are made. You should also be concerned with the color of the goods, as to whether it will fade or run, and, in the case of printed materials, as to whether it is uniform and clearly printed.

A good dye should possess these qualities: (1) it should have an acceptable color; (2) it should not be injurious to the fabric; (3) it should dye fast, that is, not run or fade.

The best-quality fabrics are usually certified by the manufacturer as to color-fastness. Every purchaser should expect a statement or guarantee from the retailer regarding the color-fastness of goods selected.

May garments be dyed in the home? Many housewives find it economical to dye such articles as dresses, curtains, and bedcovers in the home. This process is not necessarily difficult if certain precautions are followed. It is usually safe to use any of the nationally advertised dyes, provided the directions on the package are followed carefully.

It is important, however, that the exact kind of material of which the goods is made be known. Materials made of "Celanese," acetate rayon, or "Nylon" require a special dye. It is essential that the correct temperature be maintained. Dark-colored goods cannot be dyed with light colors unless the goods are first bleached. Directions for bleaching out the dyes already on the goods are given with the dye materials provided. It is often wise to take a small piece of the material to dye as a test sample in order to ensure that the correct shade will be obtained.



Atlas Powder Company

Lacquers being printed on cloth. Through the development of lacquers which may be used on cloth, the woman of today can buy dresses equivalent to or far better than those of a short while ago for a fraction of the cost

Often one may consider sending dresses or other goods to commercial dyers. The original cost of the garment should be compared with the cost of having it dyed. Another factor to consider is the condition of the garment. Obviously, it will not pay to have an old dress dyed if there is little wear left in it. Before allowing any dyer to take the garment, a guarantee as to color, fastness, shape, and size should be obtained, because very often one is disappointed with the results.

EXERCISES

1. Why did early man attempt to color the materials he used?
2. Consult some old person and ask how cloth materials were dyed in his early youth. Write up your interview.
3. How are dyes classified? Describe each class.

4. What advantages do synthetic dyes have over natural dyes?

5. Describe the differences between direct dyes and mordant dyes.

6. Explain what is meant by the terms *yarn-dyed goods* and *piece-dyed goods.*

7. Describe how a piece of goods may be dyed with the use of a mordant. What substances are used as mordants?

8. What are vat dyes? lake dyes?

9. How can the consumer tell the difference between well-dyed goods and poorly dyed goods?

10. What precautions should be observed in dyeing fabrics in the home?

11. Read in one of the references at the end of this unit about the discoverer of synthetic dyes and write a paragraph as a summary of your reading.

Problem 5. What simple chemical and physical tests may be used in identifying fabrics?

New methods must be applied. The old method of identifying fabrics was simply to feel and look. But this was before the many new fibers of today were on the market and before manufacturers had developed the art of mixing many kinds of fibers in the making of a single fabric. It is not an easy matter to analyze completely or identify all fabrics. However, it is possible to become acquainted with some simple tests which will help you greatly in distinguishing between fabrics, and with practice you may even become expert in this art.

Textiles are frequently finished in such a manner as to cover up their true identity. In such cases, inspection alone is not a sufficient guide to the kind or quality of fabrics. A knowledge of chemistry will enable you to uncover the true qualities of fabrics, which are often concealed.

The simplest tests which may be applied to most fabrics and which will be described first are (1) the strength test; (2) the breaking test; (3) the burning test. Chemical tests which may be applied will be described later in this problem.

The strength test. The wearing quality of any fabric is closely related to its tensile strength. The quickest and most convenient method of testing the tensile strength of a fabric is to grasp it firmly between the thumb and forefinger of each hand, with the ends of the thumbs touching. The thumbs are then turned so as to bring the backs together. This will cause the ends of the thumbs to be forced through the cloth. If the tensile strength is low, the thumbs will go through the cloth easily and break many strands; but if the tensile strength is high, much force will have to be applied. The test should be applied along both the warp, the lengthwise threads, and the filling, or woof, of the fabric.

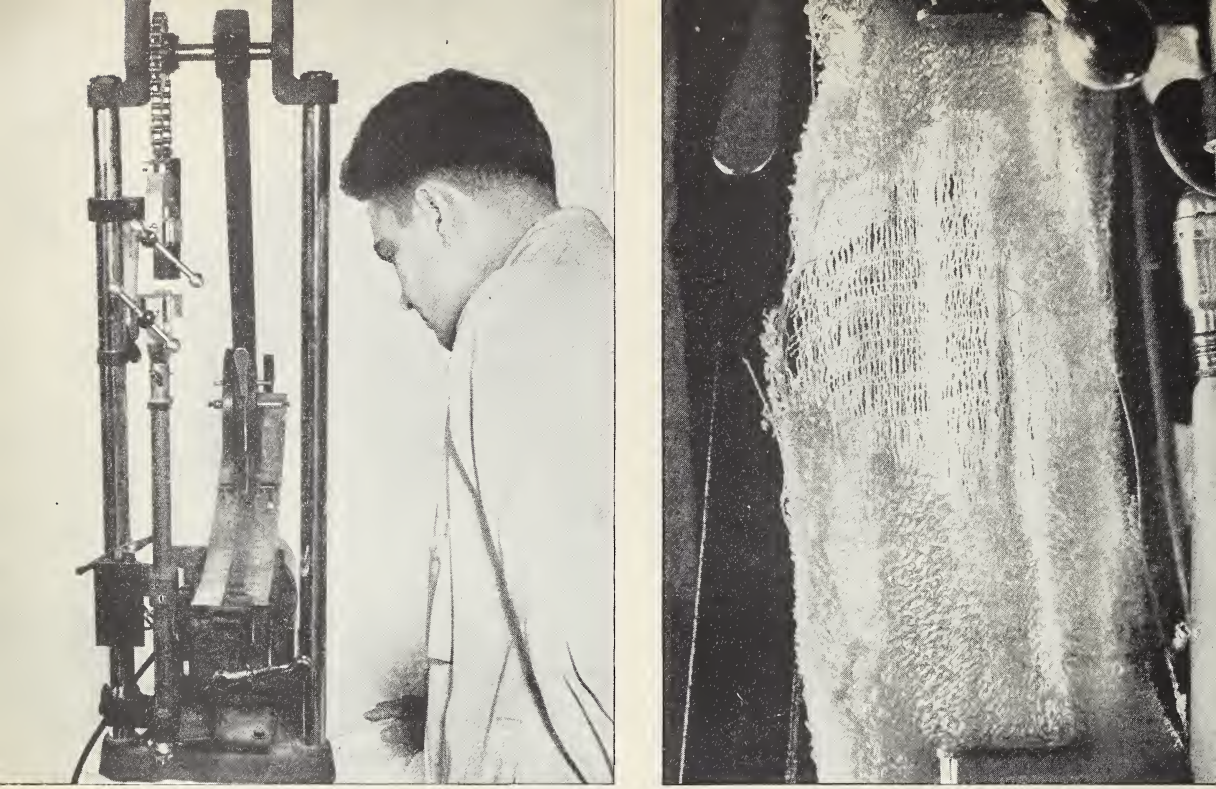
Consumers Union

Testing laboratories often use an abrasion machine, such as the one shown above, to test the wearing quality of such articles as sheets. A sheet of good quality may take 1138 turns before wearing through. The one shown here is of poor quality, as it took only 646 turns before wearing through

The breaking test. This test will enable you to determine the kinds of fibers that are used in the warp and filling of the fabric. To apply this test, draw a single thread from both the warp and the filling, untwist the yarn, hold the ends in either hand, and break the yarn with a quick pull. The ends of the broken fibers will appear as follows:

Cotton. A fuzz tuft of fibers will show at both ends.

Linen. The break will be irregular, and the fragments will be pointed.



Consumers Union

This is a breaking-test machine, used to determine the tensile strength of Turkish towels and thus their lasting quality. In the picture at the right the towel is beginning to break under the tension

Wool. The ends will have a wavy appearance.

Silk. It will break straight, and the fibers will be long and lustrous.

Rayon. It will look something like cotton but lustrous.

In all types of fibers, the breaking test will assist you in determining their length and character.

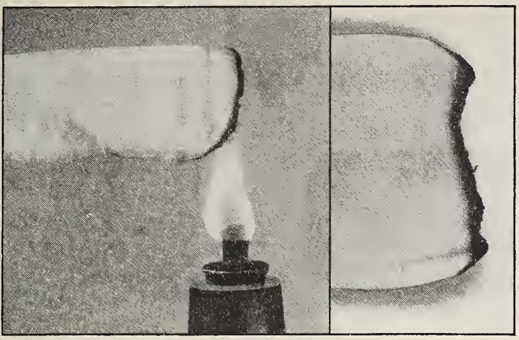
The burning test. In applying this test, it is best to use individual threads pulled from the warp and filling, although bigger samples may be used to confirm your conclusions. The burning test will enable you to distinguish between acetate rayon and the regenerated rayons, and between pure silk and heavily weighted silk and rayon. Moreover, you will be able to tell whether the threads are made of animal fibers, such as wool or silk, or from those of vegetable origin, such as cotton, linen, or rayon. Blended fabrics composed of two kinds of rayon or of rayon and silk can be distinguished by careful burning tests if individual threads taken from the warp and filling are used. However, if wool and rayon are spun together and then woven, the burning test will not detect this combination. Your equipment for the burning test is simple. Use a flat white plate or pan and a small flame such as a match flame or candle flame. You should practice on known fabrics until your senses of perception and discernment are developed.

When a flame is applied to animal fibers, they give off the plainly disagreeable odor of burning feathers or hair. A gummy bead of black residue will accumulate on the ends of the threads of animal fibers. Wool will burn slowly and leave much more ash than cotton or rayon.

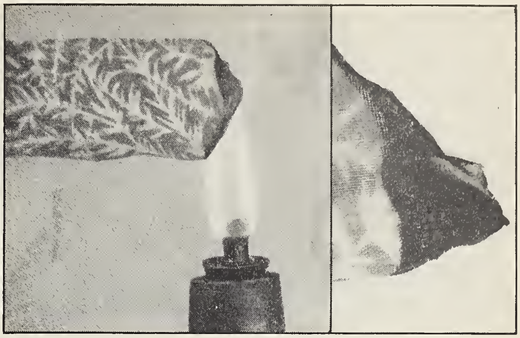
Cotton fibers burn readily with comparatively little odor and leave very little ash. Rayon, if unweighted, burns very similarly to cotton.

Unweighted silk, when ignited, will burn slowly, and the flame will extinguish itself when the silk is laid on a plate or pan. The characteristic odor and little black ball will form. Weighted silk can best be

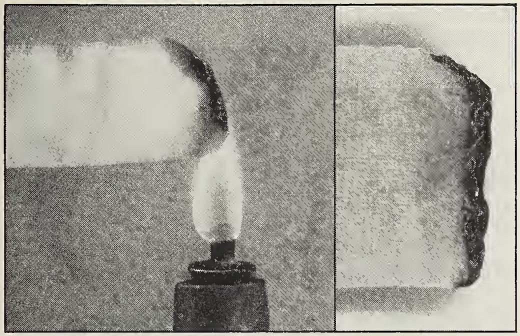
Identification of Fabrics by Burning[1]



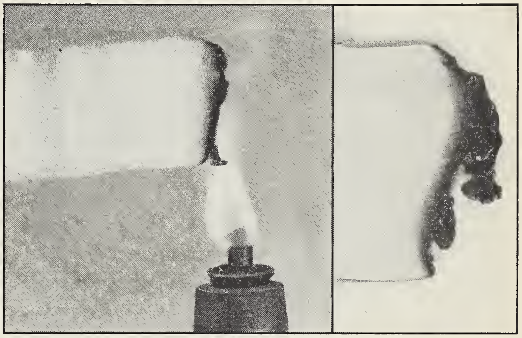
An untreated, all-cotton fabric burns almost completely, leaving practically no ash



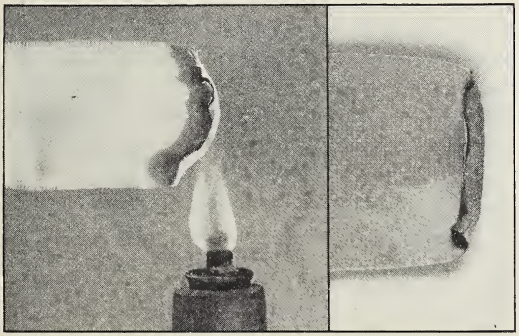
Cottons with a special finish char rather than burn completely, the ash keeping the shape of the cloth



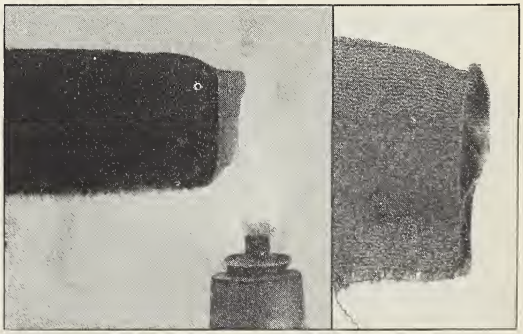
Wool does not flame but smolders as it burns. The ash collects along the edge



A pure-dye silk burns with little flame; the ash is black and shiny and forms in tiny, brittle balls along the edge of the fabric



Acetate rayon burns with a blaze. The edges curl as it fuses into a hard, brittle, round mass



A weighted silk only chars and leaves a black ash of the same shape as the cloth identified by burning a piece of the fabric. Such a sample will char instead of burning with a flame, and the ash will retain the original form of the fabric.

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[1] All photographs on this page are by Adrian J. Iorio.

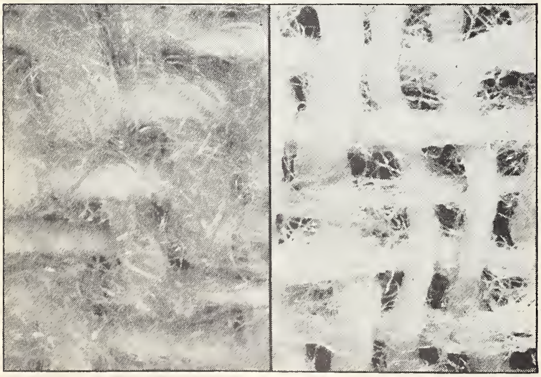
All rayon burns very quickly. The viscose and cuprammonium rayons leave practically no ash if the samples have little weighting. Burning acetate rayon gives off an odor of burning punk and leaves a shiny bead similar to that of silk, except that the bead is harder and does not crush easily between the finger and thumb, as the silk bead does.

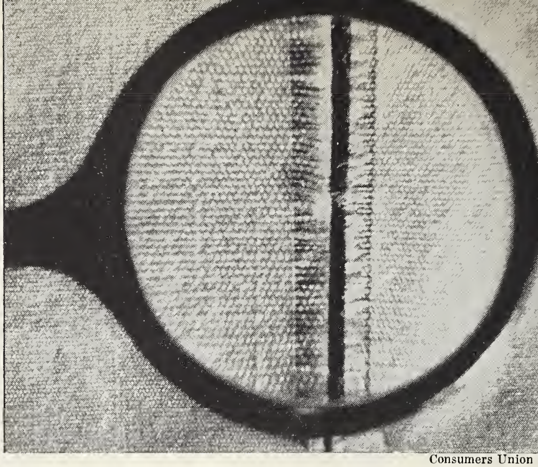
The chemical tests. There are many chemical tests which a chemist applies in the identification of textiles. The reaction of the vegetable fibers to chemicals is different from that of the animal fibers. For example, the alkalies, such as sodium and potassium hydroxide, destroy the animal fibers wool and silk. Vegetable fibers are not destroyed but instead are strengthened by dilute solutions of alkalies. Generally, the tests below can be made at home or in the laboratory with simple materials.

The hydroxide test. To show the presence of a mixture of silk or wool and a vegetable fiber, prepare a dilute solution of sodium hydroxide by dissolving two teaspoonfuls of lye in a pint of water, using a granite pan or "Pyrex" beaker. Boil the sample to be tested in this solution for from five to ten minutes. Any wool or silk will dissolve, while cotton, rayon, or linen will remain. If you weigh the sample carefully before and after performing this experiment, you may work out the percentage of animal fiber and vegetable fiber present in the sample.

These two pictures show how a fabric which is a mixture of wool and rayon is affected when heated in a solution of sodium hydroxide. The rayon (right) remains, and the wool dissolves

A. J. Iorio





Consumers Union

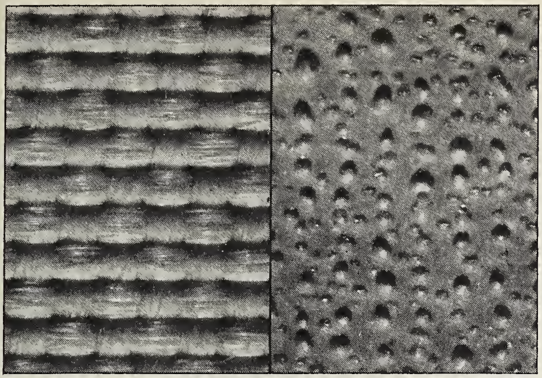
Under a hand lens, or magnifying glass, one can easily see the difference between a high-thread-count and a medium-thread-count fabric. Which of these two fabrics, the right one or the left one, has the higher thread count? Which do you think would wear longer?

The acid test. Silk will dissolve slowly in cold concentrated hydrochloric acid. Wool fibers will swell but will not be destroyed. Cotton will be only slightly affected. You may distinguish between vegetable and animal fibers with a 2 per cent solution of sulfuric acid. Place a drop of this solution on the samples to be tested and allow it to penetrate through the goods. Then place the samples between two pieces of paper and press with a hot iron. You will notice that the vegetable fibers char when so treated, but the animal fibers remain as they were.

Nitric acid test. If a few drops of nitric acid are put on various kinds of fibers in test tubes and warmed, the following reactions occur: (1) silk and wool turn yellow; (2) cotton, linen, and rayon are not changed in color.

If the samples are washed and a few drops of ammonium hydroxide are added, the yellow color changes to orange.

Miscellaneous tests. You may get some idea of what the fibers in a piece of goods are by heating samples in two dry test tubes. Hold above one test tube a moistened piece of red litmus paper and above the other lead acetate paper. Cotton, linen, and rayon will not give off any fumes which will affect these papers. Wool and silk will yield ammonia vapors, which turn red litmus blue; and wool can be distinguished from silk because the sulfide vapors



A. J. Iorio

A fabric may be tested to determine the presence of acetate rayon by being soaked in acetone. This picture shows that the heavy acetate-rayon stripes were destroyed when the material was soaked in acetone. What fact does this illustrate about cleaning rayon dresses in certain solvents?

from it will turn the lead acetate paper black. The latter action is due to sulfur, which wool contains.

Examination of the individual fibers of the warp and the filling under the microscope is of great value in identifying the materials in a piece of goods. In making this test, it is important that single threads be unraveled into their component fibers before microscopic examination. Identification can be made by comparing the microscopic image with the diagrams of the various fibers shown in Problem 2 of this unit.

Cellulose acetate, or acetate rayon, will dissolve in acetone or chloroform, but no other rayons or other fibers are soluble in these reagents.

Linen is difficult to distinguish from cotton, especially if the cotton has been treated with a dressing, or sizing. If a test is to be made, the sample should be washed and dried thoroughly. Then place a drop of ink on the sample. If it is linen, the ink will be absorbed quickly in an even circle. If it is cotton, the ink will be absorbed irregularly and not as quickly. The oil test also may be used to distinguish these two fibers. If a drop of olive oil or glycerin is applied to a thoroughly cleaned and dried sample of linen, the spot becomes translucent. Cotton so treated remains opaque. The microscopic test is the best method for the identification of linen.

Elsner's reagent (500 grams of $ZnCl_2$ and 20 grams of ZnO dissolved in 425 cubic centimeters of H_2O) will dissolve silk, but cotton, rayon, linen, and wool remain undissolved in it.

When fibers are mixed before spinning, it is extremely difficult to distinguish adulteration.

Much experimentation in the home and the laboratory, accompanied by patience, will enable you to obtain accurate results in textile-testing. This will help you to become a more intelligent buyer of clothing.

EXERCISES

1. Describe and illustrate the breaking test for identifying fabrics.

2. Describe and illustrate the strength test for identifying fabrics.

3. How may the burning test be applied in identifying fabrics?

4. List the methods that you would use to determine the presence of cotton and linen in a piece of goods.

5. How could you tell whether a piece of goods was made of cotton or wool or a mixture of the two?

6. If you suspected that a "silk" dress contained rayon, how could you be sure, one way or the other?

7. What identifying tests could you make to show the presence of a cotton and acetate-rayon mixture in a piece of goods? of a cotton and rayon mixture?

8. What tests would you make to show the presence of heavy weighting in silk? in rayon?

9. How does concentrated HCl affect the different fabrics?

10. How does dilute H_2SO_4 affect the different fabrics?

11. What solution would you prepare to show whether a piece of goods was made of animal fibers or vegetable fibers?

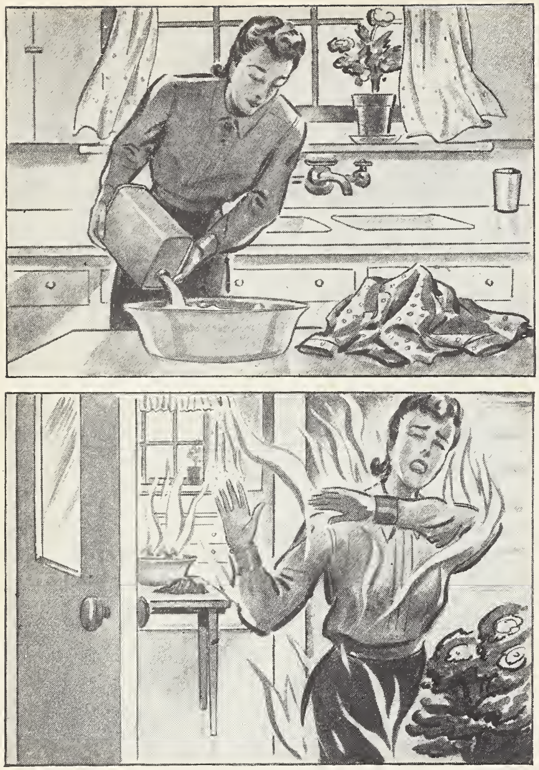
12. What chemicals are used to determine the presence of acetate rayon? of silk?

Problem 6. How should clothing be cared for?

The care of clothing is important. The life of clothing may be greatly extended if it is cared for properly. This not only will result in the saving of money, but also will make it possible for you to present a good appearance. The following things are important in the care of clothing:

1. *Airing.* Clothing should be aired frequently to evaporate perspiration and remove odors.

2. *Hanging.* Carelessly tossing clothing on a bed or over a chair has a tendency to ruin the press and causes



These two pictures illustrate the danger which may come from using an inflammable cleaning fluid. You should never use gasoline for cleaning, as the heat of friction may be sufficient to ignite the vapor

the garment to stretch and lose its shape. All clothing should be carefully placed on hangers.

3. *Pressing.* If garments are to appear well, they should be kept in press. Pressing helps to maintain shapeliness.

4. *Brushing.* Garments should be brushed or shaken frequently. This will help to remove dust, germs, and moth eggs.

5. *Cleaning.* If the dirt and perspiration are not removed, the clothing will wear out much faster than if it is kept clean.

6. *Repairing.* Tears, rips, and missing buttons give clothing an unsightly appearance. In addition, the timely repairing of a tear or rip which, if let go, may become larger may save the garment from premature consignment to the rag bag.

7. *Storing.* Clothing which is not being used should be demothed, placed in mothproof bags, and stored in sealed closets or clothesbags.

Cleaning clothes. Most cotton and linen and some silk, rayon, and wool are washable. The laundering of these materials will be discussed later, in Unit 25. This discussion will be limited to the dry-cleaning of silk, rayon, and wool garments and to the removal of spots from such garments.

There are three solvents which are most widely used in dry-cleaning in the home. These are naphtha, a high-grade white gasoline; carbon tetrachloride (CCl_4); and a mixture of the two. None of these is entirely safe or satisfactory. There is great danger of fire and explosion when naphtha is used. Many very serious accidents have occurred when this solvent was used, because a tiny friction spark will cause it to ignite. Naphtha should never be used as a solvent for dry-cleaning in the home. Though carbon tetrachloride is noninflammable, its fumes are poisonous, so that when it is used in dry-cleaning, the work should be done in a well-ventilated room or out of doors. A mixture of these two solvents will be less inflammable than naphtha. However, the carbon tetrachloride evaporates faster than the naphtha; therefore the inflammability of this mixture, after it has been used several times, is greatly increased.

Dry-cleaning in the home is much more economical than commercial dry-cleaning, but it is very hazardous. It is probably better in the long run to have your dry-cleaning done for you if the prices are reasonable. However, if you feel financially unable to have it done, you should exercise the greatest care in doing it in the home.

Spotting. There are so many factors to be considered in removing a spot or stain that it is not usually practical or economical to use other than the most simple methods. There is no substance which can be called a universal spot-remover. The chemicals that you use to remove a spot or stain depend upon the kind of spot, the kind of fabric, and the dye present in the fabric.

One rule which should always be followed is that of removing the spot or stain at once. Many substances which get on clothing will set, or harden, if not taken care of immediately. Another rule is to try sponging with cold water if the fabric is not injured by water.

It is well to remember that spot-removers are solvents. Therefore the substance to be removed

Good Housekeeping Institute

These pictures show the correct method of removing spots from clothing. What chemicals are used in spotting?

must be soluble in the remover to be used. In spotting, place an absorbent material, such as a towel or clean blotter, underneath the stained area. Moisten a clean cloth with some of the spot-remover and rub lightly from the outer edges of the spot toward the center. This will help to prevent rings. It is advisable to test the spot-remover on a part of the garment which does not show to determine if the dye in the fabric will be affected. Some of the methods of treating individual stains are given in the paragraphs which follow.[1]

Bloodstains. (1) If the material is washable, soak the bloodstain or rub it in water until it turns to a light-brown color and then wash in hot water. For silk or wool, sponge the stain with cold or lukewarm water. (2) Raw starch mixed to a paste with cold water may be used for a stain on thick material. Apply the paste and then brush it away when dry. Repeat if necessary.

Chewing gum. (1) If the material is washable, soften the gum with egg white and then wash. (2) Another treatment is to sponge with carbon tetrachloride and water.

Chocolate and cocoa stains. (1) If material is washable, it may be washed with soap and water. Javelle water (calcium hypochlorite) or a commercial bleach may be used on white cotton or linen to remove persistent chocolate stains. (2) Soak the stained portion of the fabric in wood alcohol made alkaline with ammonia water. This is a particularly effective method. (3) If the fabric is not washable, the stain may be sponged with carbon tetrachloride or naphtha to dissolve the fatty contents of the chocolate stain, and the remainder can be removed with hydrogen peroxide.

Coffee stains. (1) Fresh stains and most old ones on washable materials can be removed by ordinary laundering. A slight trace sometimes remains in the case of very heavy or old stains. Drying the material in the sun will frequently remove these, or, if the material is white, a bleaching agent, such as a commercial bleach, may be employed. (2) Pour boiling water on the stain from a height of two or three feet. This is effective on stains which are not more than a few hours old. (3) If the stains are on wool or silk material, sponge immediately with cold or lukewarm water. If a grease spot remains, remove it with carbon tetrachloride or naphtha.

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[1] Adapted from *Stain Removal from Fabrics, Home Methods*, Farmers' Bulletin No. 1474, United States Department of Agriculture.

Berry stains and other fruit stains. (1) If the stain is on washable material, stretch the stained material over a bowl or other vessel and pour boiling water on it from a teakettle at a height of three or four feet so that the water strikes the stain with some force. (2) Stains remaining after treatment with boiling water can often be bleached by moistening with lemon juice and exposing to the bright sunlight. (3) Javelle water or a commercial bleach is effective for white cotton or linen materials. Such a bleach will generally remove the dye from colored fabrics and therefore should not be used on them without trial. It cannot be used on silk or wool.

Grass, dandelion, and other fresh green foliage stains. (1) If the material is washable, use hot water and soap, as in ordinary laundering, rubbing the stain vigorously. Remaining traces of stain in white cotton or linen may be bleached out with a commercial bleach. (2) If the material cannot be laundered, sponge the stain with ether or alcohol (either wood or denatured).

Here is a quick method for removing beverage and fruit stains from washable fabrics. Stretch the stained part over a bowl and pour boiling water through the stain

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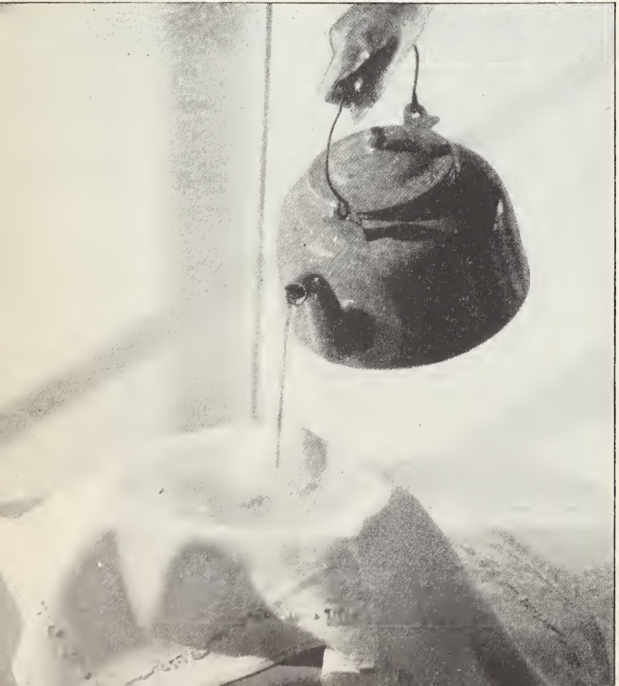
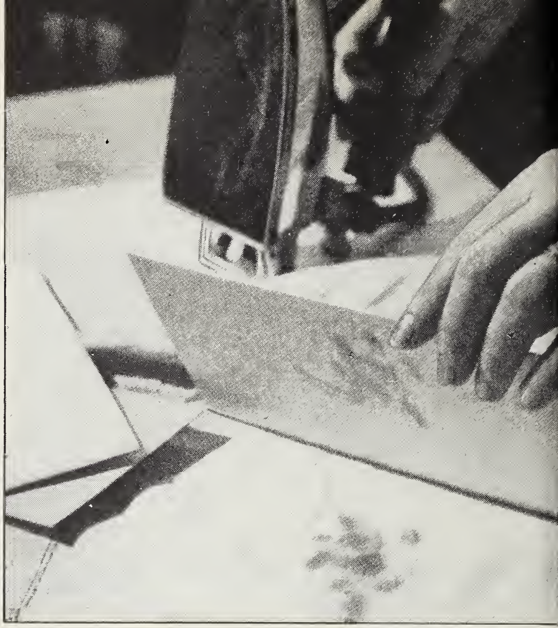


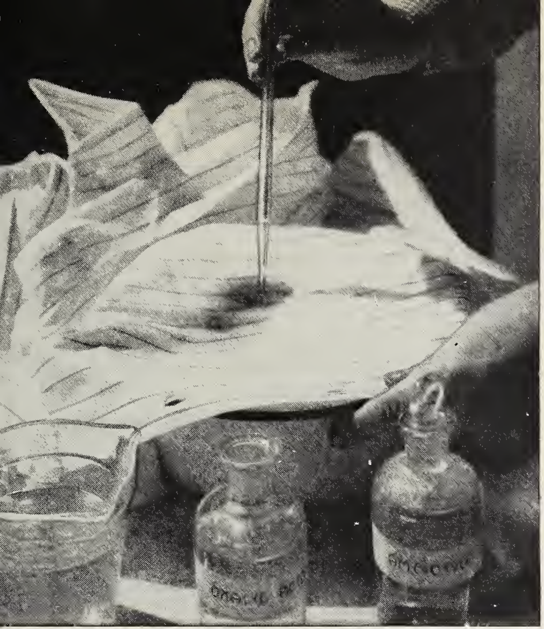


Good Housekeeping Institute

Some stains on white fabrics may be removed by means of clean white blotters and a hot iron. A piece of blotting paper should be placed under the stain and a piece on top of the stain. A hot iron is then pressed over the upper blotter

Grease and oil stains. (1) Grease spots usually can be removed from washable materials with warm water and soap, as in ordinary laundering, if care is taken to rub the particular spot thoroughly. (2) Lay the stained fabric on a flat surface and spread a layer of an absorbent, such as blotting paper, fuller's earth, brown paper, French chalk, powdered magnesia, or white talcum powder on the stain. Work the absorbent around gently and brush it off when it becomes gummy. Repeat, and if the stain is not removed, apply another layer of the absorbent and allow it to remain overnight. (3) Carbon tetrachloride, chloroform, ether, gasoline, naphtha, and benzine are effective in removing common grease, cedar oil, and vegetable oils. This is the most effective method of removing grease spots.

Writing-ink stains. (1) To an ink stain still moist apply cornmeal, salt, French chalk, fuller's earth, magnesia, or talcum powder to remove any ink not absorbed by the fibers and, to keep it from spreading, remove the absorbent when it becomes soiled and repeat. When the dry absorbent fails to take up more ink, make it into a paste with water and apply again. (2) If the fabric is washable, soap and water, as in ordinary laundering, is satisfactory for some types of ink. (3) Soak the stains in milk for a day or two and, if necessary, change the milk as it becomes discolored. Pasteurized milk usually



Good Housekeeping Institute

Ink stains may be removed sometimes by applying alternately solutions of oxalic acid and ammonia and then sponging off lightly with some soft absorbent material

is not so satisfactory for this purpose as milk that has not been heated.

Iodine stains. (1) If the material is washable, soap and water will often remove a fresh stain. (2) Sponge with rubbing alcohol. This agent can be used on materials which water would injure.

Iron-rust stains. (1) Spread the stained area over a vessel of actively boiling water and then squeeze lemon juice on the stain. After a few minutes, rinse the fabric, and repeat the process. (2) Sprinkle the stain with salt moistened with lemon juice and place in the sun. Add more lemon juice if necessary.

Milk and cream. (1) If the material is washable, rinse in cold or lukewarm water; then wash with hot water and soap. This is generally sufficient. (2) For fabrics which ordinary laundering would injure, first sponge with carbon tetrachloride or naphtha, allow the spot to dry, and then sponge carefully with water.

Paint stains. (1) If the material is washable, fresh stains are removed easily by carefully washing with plenty of soap. Older stains sometimes can be removed in this way if they are first softened by rubbing oil, lard, or butter into them thoroughly. (2) Sponge the stains with pure turpentine or wash the whole article in it if the spots are large or scattered. Rinse several times in fresh quantities of the solvent.

Paraffin stains. (1) Place clean blotting paper on an ironing board. Then place the stained material, paraffin side down, on the blotting paper and press with a warm iron. (2) If a trace of the stain remains after the treatment recommended above, sponge with carbon tetrachloride or naphtha.

Tea stains. (1) If the stains are on cotton or linen and are a few days old, soak them in borax solution (one-half to one teaspoonful of borax to one cup of water) and then rinse in boiling water. (2) Use potassium permanganate for stains which resist other reagents. Dissolve one teaspoonful of permanganate crystals in one pint of water. Apply the solution to the stain with a medicine-dropper, allow it to remain for five minutes, and then sponge it off with hydrogen peroxide. Try this on a sample of the material first to be sure that it does not remove the color.

Tobacco stains. (1) If the material is not washable, sponge the stain with water. If stains on washable materials cannot be completely removed by washing, bleach them in the sun or moisten them with lemon juice. (2) Traces of color remaining on wool fabrics after sponging with water can be removed sometimes by sponging with alcohol.

Water spots. Some silks and wools are spotted by water. A satisfactory method for removing such spots is to dampen the entire material evenly and press it while still damp. This may be done either by sponging the material carefully with clean water or by shaking it in the steam from a briskly boiling teakettle until it is thoroughly damp. Scratching with the fingernail or a stiff brush is sometimes sufficient.

Protection against moths. Out-of-season clothing which is not being worn should be stored. Before placing the garments in storage, they should be brushed and shaken thoroughly and then exposed to the direct rays of the sun for a considerable time.

Clothing made from the animal fibers wool and fur may be damaged by moths. If care is taken in cleaning the clothing so that all moth eggs are removed, the garments can be stored in a sealed bag or chest without danger of destruction. However, it is almost impossible to be certain that all moth eggs have been removed, and therefore other precautions should be taken.

The two best and least expensive chemicals used to destroy moths are naphthalene (moth balls) and paradichlorobenzene. Both these chemicals are destructive to moths when the chemicals are used in tightly closed containers so that the fumes cannot leak out. When clothing is placed in a cedar chest or tight trunk, either of these chemicals should be sprinkled in the folds of the clothing, about 1 pound of the chemical being used to each 8 cubic feet (abbreviated cu ft) of storage space. If this procedure is followed, you may be certain that no damage will result from moths.

A cedar chest which is well made of good-quality cedar will protect clothing against moths. The volatile cedar oils are toxic to moths. Cedar closets are valuable only if they are well built and kept tightly closed.

There are many products advertised for killing moths. Most of them are expensive, and none are more effective than naphthalene and paradichlorobenzene. Many cleaners advertise that they can mothproof your clothing. Permanent mothproofing is impossible. Arsenic gases and hydrocyanic gases are sometimes used to mothproof clothing. The poisonous nature of these gases makes such mothproofing undesirable. Some companies sell moth cakes to be hung in clothes closets. These, however, are not dependable unless the closet can be tightly closed so that the fumes are confined within it.

EXERCISES

1. What factors are most important in the proper care of clothing?

2. What dangers attend the home cleaning of clothing? What materials are safest to use?

3. How do spotting agents remove spots?

4. What stains can be removed by carbon tetrachloride?

5. What stains are best removed by water?

6. How can you prevent the formation of rings in removing spots?

7. How are ink stains best removed?

8. What purpose do potassium permanganate and hydrogen peroxide serve in removing stains?

9. How should garments be protected against moths?

10. What chemicals are used to kill moths? What ones are used to keep them from living in a confined space?

PROBLEMS FOR FURTHER STUDY

1. What are the latest developments in the making of synthetic fibers for clothing? Write to the Bureau of Home Economics, Department of Agriculture, Washington, D.C.

2. What information about construction, fiber content, color, and durability is available on the labels of clothing sold in your locality?

3. What is being done by the government and textile-manufacturers to promote better labeling of textiles?

4. What is the price range of suits, dresses, and overcoats sold in your community?

5. What are your state and local governments doing to promote honest advertising of textiles?

6. Collect as many samples of different fabrics as you can obtain from local stores and test them to determine what fibers are present.

7. How are fabrics finished by chemical processes to increase their durability and beauty?

8. How are the strength and durability of fabrics determined by mechanical methods? Could you devise an apparatus to test the wearing quality of stockings?

9. How may one determine the difference in heat conduction of different kinds of fabrics?

10. How are dyes made from coal tar?

11. What methods of cleaning and mothproofing are used in your community?

12. How has the mass production of textiles lowered the cost of clothing to the average consumer?

13. What are the consumer organizations which attempt to inform consumers of the best values in clothing? Are their findings reliable?

14. How are rubberized fabrics made?

15. How is "Cellophane" clothing made?

16. How does the clothing of the people of different nationalities differ?

17. What are the chemical processes used in tanning leather?

18. Why are there so many grades and prices of leather?

19. How is artificial leather produced?

20. How is fur dyed?

21. What specific knowledge must you have to buy clothing and textile fabrics intelligently?

UNIT EXERCISES

A. In each of the following statements supply the missing word or words which will complete the statement. Write your answers on a separate sheet of paper. Do not write in this book.

1. An increasing use of clothing has accompanied the growth of --(?)--.

2. One important reason for studying the chemistry of clothing is to learn of the different --(?)-- out of which clothing may be made.

3. One may identify different --(?)-- by means of --(?)-- and --(?)-- tests.

4. Clothing protects the --(?)-- of the body.

5. Clothing may be made of --(?)-- or --(?)-- fibers.

6. Wool fibers belong to a class of organic compounds known as --(?)--.

7. Silk differs from wool in that it does not contain the element --(?)--.

8. Wool is a warm fiber because it --(?)-- "dead" air.

9. Wool fibers are from one to --(?)-- inches long.

10. The fact that woven wool is quite --(?)-- causes wool clothing to hold its shape well.

11. Raw silk fibers are composed of two protein substances, known as --(?)-- and --(?)--.

12. The diet and food supply of a fur-bearing animal will determine the --(?)-- of its fur.

13. Another factor affecting the --(?)-- of the fur is the --(?)-- of climate in which the animal lived.

14. The two kinds of hairs on any fur-covered animal are known as --(?)-- and --(?)--.

15. Pure cotton is known chemically as --(?)-- and has the formula --(?)--.

16. Mercerized cotton is cotton which has been immersed under tension in cold --(?)--.

17. Linen is made up of practically pure --(?)--.

18. Linen comes from the --(?)-- plant.

19. Rayon is technically known as --(?)-- cellulose.

20. Most rayon is made in the United States by the --(?)-- method.

21. In making viscose rayon cellulose is put into --(?)-- by treating it with NaOH and CS_2.

22. Rayon may be made by dissolving cotton treated with --(?)--, in --(?)--.

23. A fiber which resembles wool fiber may be made from --(?)--, a product of milk.

24. The ability of a fabric to absorb water is known as its --(?)-- power.

25. An animal fat known as --(?)-- is obtained as a by-product in the processing of wool for weaving.

26. Wool and silk fibers are dissolved when put in --(?)--.

27. Skins and --(?)-- may be quickly tanned with --(?)-- salts.

28. Furs are bleached with SO_2 or --(?)--.

29. Grease stains may be removed by sponging with a small amount of --(?)--.

30. When the mordant and the dye are mixed together before either is placed on the cloth, the mixture is known as a --(?)-- dye.

B. Some of the following statements are true, and some are false. On a separate sheet of paper write the word *true* for those which are true and the word *false* for those which are false. Write correct statements for those which you believe to be false. Do nothing for those about which you are doubtful.

1. Wool and silk are the same in composition.

2. Wool and silk both belong to the class of compounds known as proteins.

3. Wool is known as the warm fiber.

4. Wool is hygroscopic.

5. An individual wool fiber is approximately $\frac{1}{200}$ inch in diameter.

6. Wool absorbs heat readily.

7. Wool is thermostatic.

8. Silk is a fiber made by only one kind of worm.

9. Silk fibers are the longest of all natural fibers.

10. Silk fibers are weak and fragile.

11. Most of the silk used in this country is imported from Japan.

12. Furs and skins have approximately the same chemical composition as wool.

13. Leather clothing is warm because it permits circulation of air.

14. Leather is a compound formed by subjecting the skins of animals to oxidation.

15. Cotton fibers are made of cellulose.

16. The empirical formula of cellulose is $C_{12}H_{22}O_{11}$.

17. Cotton and sugar belong to the same chemical family and are known as carbohydrates.

18. Cotton fibers look like twisted ribbons under the microscope.

19. Cotton fabrics crush easily because of the nonelasticity of the fibers.

20. Linen is a good conductor of heat.

21. Cotton is weakened when treated with cold NaOH.

22. Ramie is a vegetable fiber similar to linen.

23. Linen fibers are translucent.

24. The maximum annual production of rayon in the United States has never exceeded one million pounds.

25. Rayon is made from air and water.

26. "Nylon" is a synthetic fiber made from cellulose.

27. Rayon increases in strength when wet.

28. Spun-rayon fabrics are difficult to distinguish from fabrics made from natural fibers.

29. "Nylon" is more elastic than rayon.

30. Sulfuric acid is used in cleaning wool to make it ready for weaving.

31. Iron and tin salts are used in weighting silk and rayon.

32. Dyed furs last longer than undyed furs.

33. Tannic acid is obtained from the bark of trees.

34. Raw hides are dehaired by soaking them in NaOH.

35. Removing the hair from hides is known as depilation.

36. To complete the process of the bark tanning of leather requires about half a year.

37. Acetate rayon will dissolve in carbon tetrachloride or chloroform.

38. Synthetic dyes are less brilliant than natural dyes.

39. Synthetic dyes are made from coal tar.

40. $Fe_2(SO_4)_3 + 6\ NH_4OH \longrightarrow 2\ Fe(OH)_3\downarrow + 3(NH_4)_2SO_4$

41. Cotton fibers burn readily with little odor.

42. When burned, an animal fiber will leave no residue.

43. All rayon fibers burn slowly.

44. When a weighted sample of silk or rayon is burned, the ash retains the original form of the fabric.

45. If a drop of oil or glycerin is put on a piece of cotton, the cotton becomes translucent.

46. Soapy water is a good solvent for most stains.

47. Paradichlorobenzene is an effective chemical to use against moths.

48. Permanent mothproofing is impossible.

49. Carbon tetrachloride is a universal solvent for all stains.

50. It is inadvisable to clean clothes at home.

C. On a separate piece of paper match each word or group of words in Group II with the word or group of words in Group I which it describes, by writing together its number and the number of the word or group of words in Group I.

Group I

1. **Rayon**
2. **Acetate rayon**
3. **"Nylon"**
4. **Lanolin**
5. **Boiled-off silk**
6. **Combing of wool fibers**
7. **"Vistra"**
8. **Bemberg rayon**
9. **Alizarin**
10. **Substances which will make dyes fast**
11. **Two per cent solution of H_2SO_4**
12. **Moth balls**

Group II

1. An animal fat which contains cholesterol
2. Carding
3. Silk from which the sericin has been removed
4. Rayon made by the cuprammonium process
5. A substance made from air, water, and coal
6. A dye obtained from coal
7. Hydrolyzing salts
8. Regenerated cellulose
9. A solution used to distinguish between animal and vegetable fibers
10. Naphthalene
11. Synthetic cotton
12. Rayon made with acetic acid

REFERENCES FOR FURTHER READING

Caplin, J. F. *Knitting: Its Products and Processes.* Dry Goods Economist, New York, 1927.

Carver, T. *Textile Problems for the Consumer.* The Macmillan Company, New York, 1935.

Clark, E. R. *Wearing Apparel: Its Manufacture, Utility, Selection, and Care.* University of Pittsburgh, Pittsburgh, Pennsylvania, 1928.

Curtiss, Harry. *Testing of Yarn and Fabrics.* Pitman Publishing Company, 2–6 West 45th Street, New York, 1938.

Denny, G. G. *Fabrics and How to Know Them.* J. B. Lippincott Company, Philadelphia, 1928.

Eaton, Jeanette. *Behind the Show Window.* Harcourt, Brace and Company, New York, 1935.

Eaton, Jeanette. "Solving the Mystery of Textiles," *Pictorial Review*, September, 1934, pp. 22–50.

Haven, G. B. *Mechanical Fabrics.* John Wiley & Sons, Inc., New York, 1932.

Preston, J. M. *Modern Textile Microscopy.* Emmott & Co., Ltd., London, 1933.

Reich, Edward, and Siegler, C. J. *Consumer Goods.* American Book Company, New York, 1937.

Scott, Clarise L. *Quality Guides in Buying*, Leaflet No. 105, United States Department of Agriculture, Washington, D.C.

Tratinan, S. R. and E. R. *Textile Analysis.* Charles Griffin & Company, Ltd., London, 1932.

UNIT 18

Chemical Hobbies

Not so many years ago, almost all homes were self-sustaining. Shelter, food, and clothing—in fact, all the necessities of life—were produced by members of the family. This required a co-operative effort in which each person in the family shared. The labor required to provide the home with the necessities of life usually occupied all that part of the day not needed for sleeping and eating. Leisure time was almost unknown.

Even when industry first began to flourish, leisure time was not a problem. Those who labored in industry were required to work ten or twelve hours a day for six or seven days a week. When a day's work was done and the many family chores were completed, little time remained which could be called leisure time.

In these modern times many changes in living have taken place. Inventions have reduced the work in the home to the point where most families find it difficult to keep their children occupied. Laboring conditions have changed so that the eight-hour day and the five-day week are common. Not only the children, but those who provide for the family, have considerable time over and above that required for working, eating, and sleeping. The average person has from three to five hours a day which may be considered leisure time.

In more recent years society has been confronted with the problem of not having enough jobs for those who want work. Even in normal times many people are out of work. Little effort has been made to provide such people with constructive ways to spend their leisure time.

Extensive surveys have been made in many parts of the country to determine the relationship between the ineffective use of leisure time and crime. In almost every instance it has been discovered that crime is most likely to occur when people are out of work and without wholesome activities to occupy their leisure time. One survey in a large city shows that in those areas where community recreational facilities are not adequate, juvenile crime is most prevalent. This same city has greatly reduced crime by providing enough recreational centers to care for the leisure time of the young people.

In this unit an attempt will be made to show you the possibilities in the field of hobbies for the constructive use of leisure time.

It is not necessary for you to adopt a hobby solely on the basis of its value to society. The important thing is to select a hobby that is interesting to you. The pursuit of such a hobby will give you a feeling of accomplishment which will bring you much satisfaction. And there is always a possibility that your hobby may develop into a means of earning money. Many young persons who have successfully pursued hobbies, such as photography, collecting, constructing model airplanes, and the like, have

An interesting hobby, such as photography, adds greatly to the enjoyment of living

Photographed on Agfa film

found that their hobbies either have provided them with remunerative part-time work or have led directly to a successful vocation.

Chemistry has much to offer in the way of hobbies. Some of the most popular hobbies today are chemical hobbies. In this unit, only hobbies closely related to chemistry will be discussed. The following hobbies will be given consideration:

1. Photography
2. Home laboratories
3. Collection of minerals
4. Crime detection
5. Etching glass and metal
6. Chemical microscopy
7. Home manufacturing
8. Electroplating
9. Soilless culture of plants

It is not contended that everyone should adopt one of these hobbies. Rather, it is hoped that you will become acquainted with some of the hobbies related to chemistry. Moreover, in the study of this unit, you should learn how a hobby may be developed so that you may be more intelligent in selecting and pursuing a hobby of your own.

PURPOSES TO BE ACHIEVED

1. To help you to realize the necessity of a hobby.
2. To acquaint you with some of the chemical hobbies.
3. To aid and stimulate you in adopting a hobby.
4. To show you how a hobby may be successfully pursued.

PROBLEMS TO BE SOLVED

1. How can I pursue photography as a hobby?
2. How can I pursue other hobbies which involve chemistry?

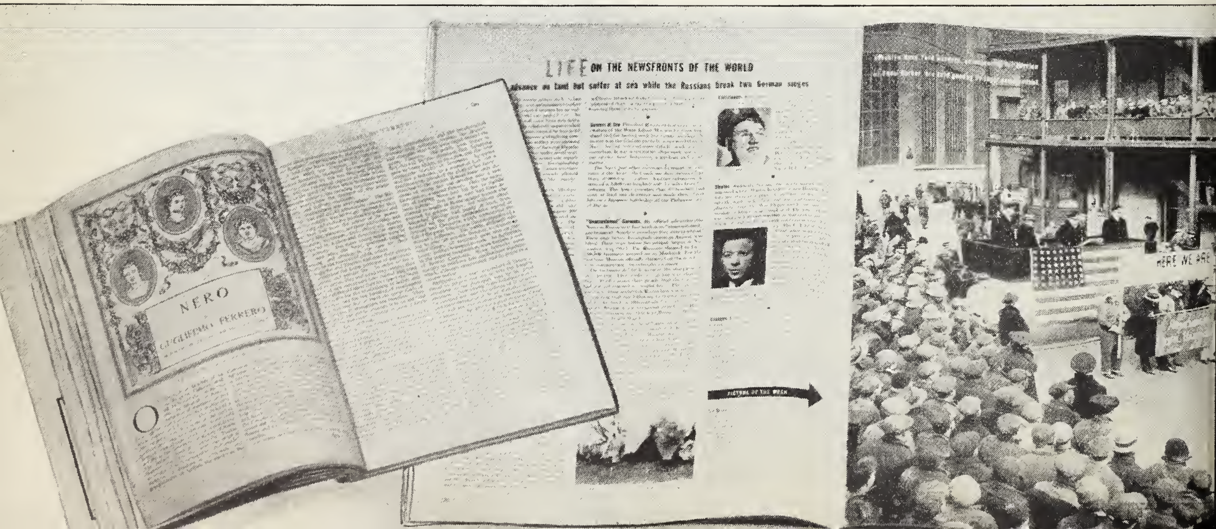
Problem 1. How can I pursue photography as a hobby?

The wonders of photography. Almost everyone is acquainted with some of the wonders of photography, but few are aware of all the ways in which it has affected our lives. Let us consider some of the improvements brought about by photography.

If you were to turn through the pages of any book or magazine which was published fifty years ago, you would be surprised to find comparatively few pictures or illustrations. Many publications in those days were drab and uninteresting because very little attempt was made to visualize the content. Almost all printed matter is made more effective, more readable, and more enjoyable when modern, lifelike photographs are used for illustration. The power of photography has been demonstrated in recent years by the unusual success of several magazines which are almost entirely pictorial.

Photography has done much to make our world one large community. In the past we were content to read about world affairs, but our understanding was greatly hampered because we could not visualize them. Today we are not satisfied just to read about current happenings. We expect to see them also. Photography, with the aid of other inventions, such as the wirephoto, has made it possible

A modern magazine, compared with one of thirty years ago, is more interesting because it contains many photographs



for us to see today's news today. Through photography we have been able to see into all parts of the world, to understand the customs and habits of other peoples, and to bring the whole world into our homes.

Have you ever considered the contribution of X-ray photography to the well-being of mankind? It has made possible an understanding of the human body which would not have been possible without it. X-ray pictures have aided in the advance of medical science by helping to locate bodily defects, such as fractures of the bones, and many other conditions of the body which could not otherwise have been properly discovered and located.

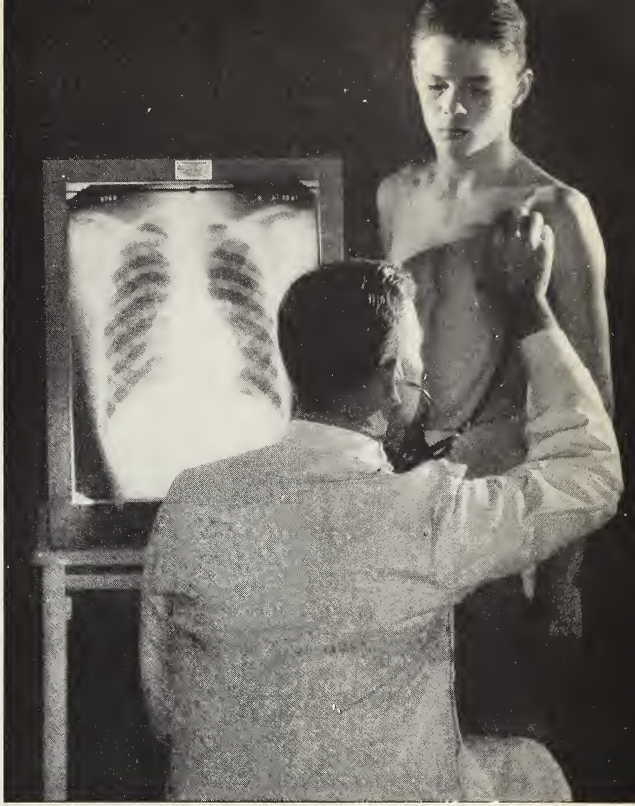
Photography has done much to make life more pleasurable. It is interesting and educational to take a trip to see new, unfamiliar parts of our country and of the world. However, much added enjoyment can be gained in reliving such a trip by occasionally looking at photographs which you have taken. Think of the many pleasant hours you have spent in motion-picture theaters. What a drab life most of us would live without motion pictures!

Photography has not in any sense realized its greatest possibilities. New uses are being discovered every day. One of the newest is television, which may soon be an integral part of every radio set.

During the past ten years photography, as a hobby, has gained great popularity. The candid camera has done much to create a new interest. The taking of pictures in color is especially appealing. There are so many different things that can be done in photography that one could hardly exhaust its possibilities even in a lifetime.

How to select a camera. The most important parts of a camera are the lens, shutter, diaphragm, and box. The lens is the most important and most costly part. Its function is to gather in the light rays from the object or objects to be photographed and converge them upon the film. The diagram shown at the top of page 282 illustrates the action of the lens.

A camera lens in a simple box camera is convex. Although a single convex lens will serve well, it is not capable of producing a perfect image. It does not focus the image sharply at the outer edges of the film. This is very evident to a person who has had considerable experience with cameras. To overcome this difficulty, an anastigmat lens has been designed. This lens is one made up of two or more lenses which produce an image which is everywhere sharp. Anastigmat lenses are used only in the more expensive cameras.

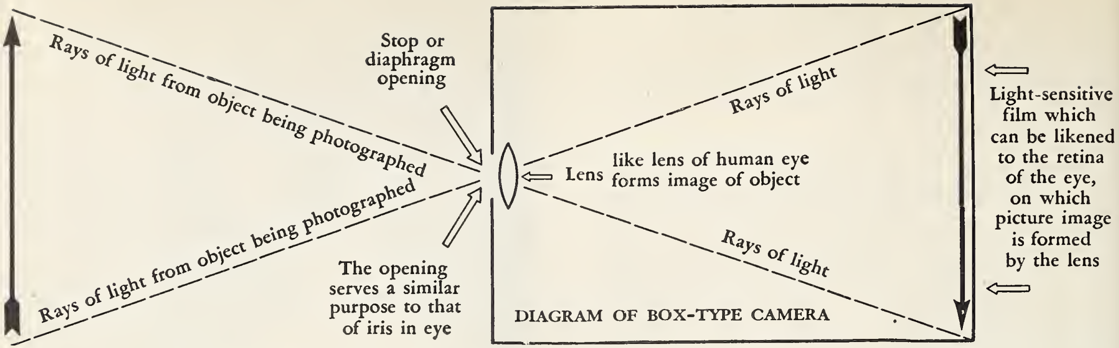

Eastman Kodak Company

The X ray has made medical science a more exact science

The distance from the center of a lens to the point at which parallel light rays are brought to a focus is called the focal length of the lens.

The diaphragm, or "stop," opening determines the amount of light that passes through the lens to the film in a given length of time. In some box cameras the diameter of the diaphragm cannot be changed, but in the more expensive cameras it can be adjusted according to the conditions of light when the picture is taken.

The ratio between the focal length of the lens and the diameter of the diaphragm is called the relative aperture or the "f" value of the lens. For example, a camera with a lens of 2-inch focal length and a


Rays of light from object being photographed
Rays of light from object being photographed
Stop or diaphragm opening
The opening serves a similar purpose to that of iris in eye
Lens
like lens of human eye forms image of object
Rays of light
Rays of light
DIAGRAM OF BOX-TYPE CAMERA
Light-sensitive film which can be likened to the retina of the eye, on which picture image is formed by the lens

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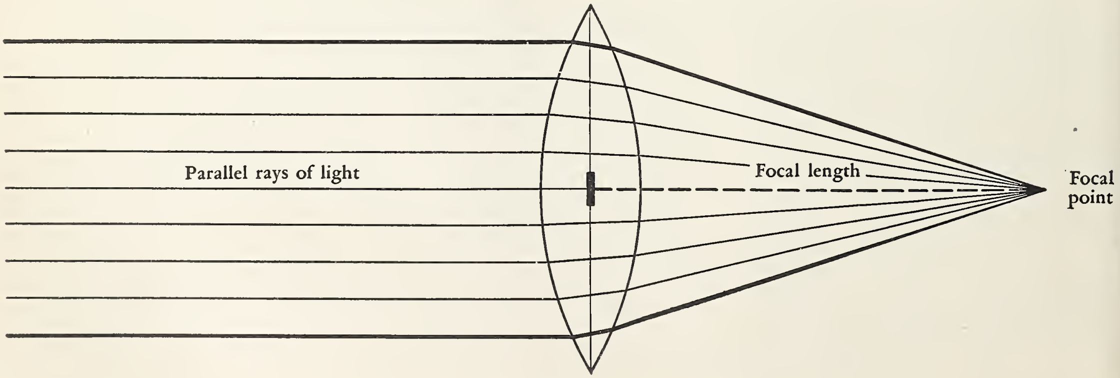
The action of the lens of a camera is similar to that of the lens of the human eye

maximum stop opening of .5 inch will have an f value of 2 ÷ .5, or f.4. Other lenses may be designated as f.22, f.11, f.6.5, f.4.5, f.2.5, or any other value, depending on this ratio. The lower the f value, the faster the lens and usually the more expensive the lens. The f value assigned to a lens is its lowest f value and is calculated for the maximum diaphragm opening of the camera. The f value may be increased by decreasing the diaphragm opening. The lens in a box camera is usually between f.11 and f.16.

Another factor that must be taken into consideration in buying a camera is the shutter, which determines the time of exposure. The rotary shutter, used in the box camera, generally has a fixed speed of $\frac{1}{25}$ of a second. The more expensive cameras have complex shutters which will give speeds up to $\frac{1}{500}$ of a second; still more expensive cameras have shutters which will produce speeds up to $\frac{1}{1250}$ of a second. Regulation of the shutter speed is especially necessary when taking moving objects. If a clear picture is to be obtained, the object must be "stopped"; that is, the object must move little, if any, while the shutter is open. An automobile traveling 65 miles an hour moves 88 feet in a second. This means that the car would travel about three and a half feet while the shutter of a box camera ($\frac{1}{25}$ second) was open. Such movement of an object results in a blurred picture.

The quality of the lens is of the utmost importance. It depends upon the kind of glass and the skill with which it was ground. It is well known that certain companies have, for many years, been noted

Parallel rays of light are bent by the lens so that they converge at a point



for making high-quality lenses. If you are to buy an expensive camera, you should spend considerable time in learning about the quality of lenses.

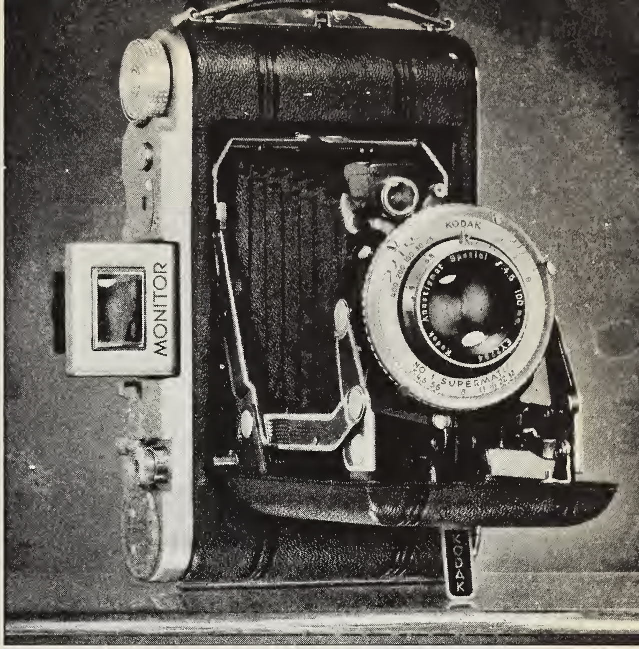
An exposure meter may be purchased, which will accurately determine the f value and the speed of the shutter to use in taking any picture. A few cameras are now equipped with built-in exposure meters. This is an added feature.

After having acquired a good understanding of cameras and lenses, you must next determine the kind of pictures you will want from the camera you buy. If you decide that you would like prints, you will have to determine the size you want. Miniature cameras, which provide prints an inch square or less, are usually unsatisfactory unless the picture is enlarged. This necessitates enlarging equipment. Most people are not satisfied with a print under $2\frac{1}{4} \times 3\frac{1}{4}$ inches. The popularity of the candid camera has resulted in the introduction of the 35-millimeter film. A transparent positive made from the negative of this film can be shown through a projector. A camera of this type requires the purchase of either an enlarger or a projector.

It is generally advisable for the beginner to start with an inexpensive box camera. It is possible to get excellent pictures with such a camera, although the likelihood of success is less than with a more expensive camera having a faster lens. After the beginner has experimented with the box camera, the next purchase will depend upon his interest and desire to explore further. Certainly, no one should buy a more expensive camera unless he is willing to study the most effective way to use such a camera. Many disappointments have come to owners of expensive cameras because they have been unwilling to learn how to use such cameras. Box cameras can be purchased which are so simple that they are foolproof. A good box camera may have an adjustment for a time exposure and another to take a picture closer than fifteen feet from the camera.

There are many "gadgets" that can be bought as accessories for a camera. Most of these are designed for the more expensive cameras. For many amateurs such accessories as range-finders, exposure meters, and filters will become necessities.

Selecting the film. Most companies that manufacture film for cameras produce three qualities. Thus one company makes an inexpensive film known as regular film. For five cents a roll more, you can buy a much more sensitive film; and for another five cents, you can buy an extremely fast film. It is generally understood that film of the next quality better than regular film is best for general use.



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This camera is typical of the finer folding type. What adjustments can be made in using this camera?

There are also several grades of print paper. As with the film, the regular-quality paper will not give an amateur the best results. For the little difference in price, a better quality than the regular will assure more successful prints. Enlarging paper is much faster than ordinary print paper.

Taking the picture. Snapping a picture with a box camera is a very simple mechanical process. With many such cameras no adjustments are necessary. The process involves that of looking through the view-finder until you see the picture you desire to take and then pushing the lever which opens and closes the shutter. In other cameras it is necessary to set the timing, the diaphragm opening, and the distance between the lens and the film. Such adjustments can be made successfully only by a careful study of the varying conditions under which pictures are taken and with a full understanding of the camera which is being used.

The average person who adopts photography as

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This woman is cementing lens elements for use in cameras

a hobby soon becomes dissatisfied with taking just ordinary pictures. The ability to take pictures which are artistic and different requires considerable study. The references following this discussion list books which will help you to develop this skill.

The chemistry of film exposure. Chemically, the taking of pictures is based on the sensitivity to light of the compounds silver chloride, silver bromide, and silver iodide.

The film is usually cellulose acetate, although glass plates are often used by commercial photographers. Upon one side of the film is placed a solution of gelatin in which is suspended the silver salts. When the film is exposed by opening the shutter of the camera, the light starts the reduction of the silver salts in proportion to intensity of the light which is reflected from different parts of the object that is being photographed. In other words, the light parts of the object cause much reduction of the silver salts, while the dark parts, which reflect little light to the film, cause little, if any, reduction.

The reduction is not complete, so that no free silver is deposited on the film. One explanation of the chemical action is that the silver halides (chlorides, bromides, and iodides) are reduced to the subhalides, such as silver subbromide (Ag_2Br), as shown in this equation:

$$2\,AgBr + \text{light} \longrightarrow Ag_2Br + Br \cdot \text{gelatin}$$

The gelatin absorbs the bromine, thus preventing the reaction from reversing; that is, the bromine, if not absorbed, would unite with the silver subbromide to form AgBr again, and the net result would be no reaction at all. Because of this, the film does not have to be developed immediately.

The final reduction of the partially reduced halides to free silver takes place when the film is developed. A full explanation of film development will be given later in this discussion.

Darkroom equipment. In equipping a darkroom, you can spend as much or as little as will fit your particular budget. In this discussion most attention will be given to the minimum of equipment, which can be obtained with a small expenditure.

Almost any room or corner in your home can be used for a darkroom, especially if you do the developing and printing at night. It is desirable to have running water but not absolutely necessary. The equipment can be set up in a few minutes and therefore can be easily stored away when not being used. The bathroom or a location near the laundry tubs in the basement is the most popular location.

This inexpensive box camera will take very good pictures. What adjustments may be made in using this camera?

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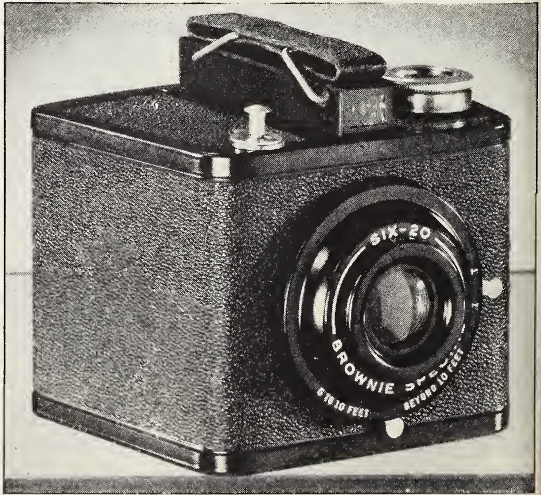
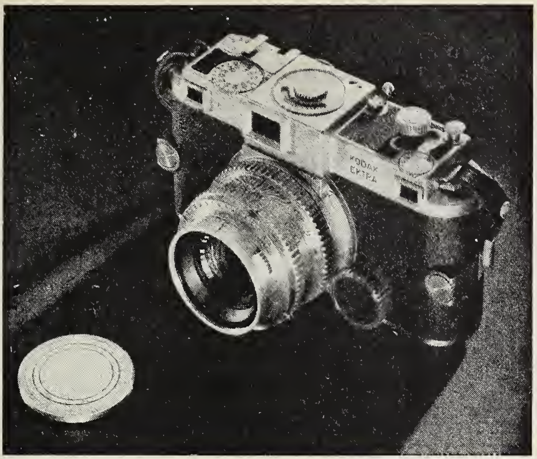




Eastman Kodak Company

This 35-millimeter camera is typical of the finest precision miniature cameras

It is essential that you either purchase a safety light from a photographic supply house or cover an ordinary light bulb with orange-colored paper or cloth.

The printing box can be purchased at a cost of about $4 or can be made for less than $1. The box should be about 8 × 10 × 12 inches in size. On the 8-inch side near the bottom should be fastened a light socket, which should be wired to a switch on the outside of the box. On the bottom of the box, wire in another socket and place in it an orange safety-light bulb. A piece of ground plate glass should be fitted into the top of the box after a 40-watt frosted bulb is placed in the socket. The distance from the center of the bulb to the plate glass should be 8 inches. Next, paste on the plate glass strips of black paper so that they will produce a rectangular mask which will provide a margin for the size of picture that you will be printing.

At least three pans are necessary. These pans should be white-enameled and at least 8 × 10 × 2 inches in size. They can be purchased at any hardware or variety store for 25 cents or less apiece.

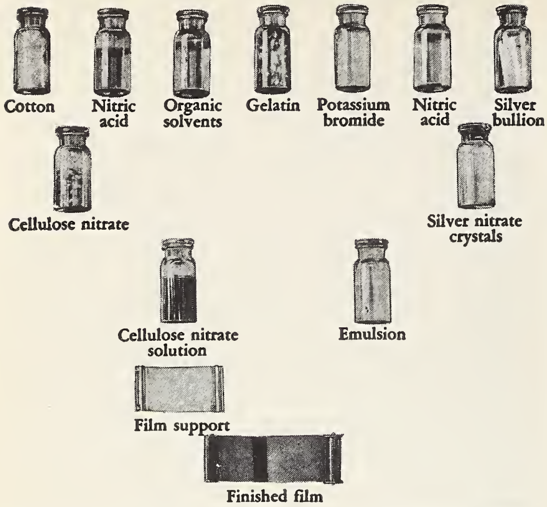
Two chemicals are necessary in the developing and printing process—a developer and a fixer. Any salesman in a photographic supply house will recommend to you a developer which will serve well in developing both the negative and the print. It is most economical to buy the developer in quantities large enough to make up a half-gallon or gallon of developing solution. The acid-fixing bath may be made by buying acid-fixing powder and dissolving it in water as described on the package. Both these solutions should be kept in dark-colored bottles and stored in a dark place.

You will also need an 8-ounce graduated, or measuring, cup and some print paper. For a beginner, it is best to buy only one kind of paper, such as No. 2 contrast glossy. As you learn to make prints, you will want to use other contrast print papers. Print paper is most economically bought in half-gross or gross lots.

The only other equipment which is absolutely necessary is either a japanned ferrotype plate or a similar plate which has a chromium finish. This plate is used for drying the prints.

There are many sizes and kinds of film

CHEMICAL STAGES IN THE MANUFACTURE OF FILM



Eastman Kodak Company

Materials used in the production of the film support and the emulsion from which the finished photographic film is made

The following list, with prices, will give you the approximate minimum cost of darkroom equipment:

Exposure box (printing box)	$1.00
3 pans	.60
Developer (to make ½ gallon solution)	.35
Acid-fixing powder (1 pound)	.25
8-ounce measuring cup	.10
½-gross print paper	.85
Chromium drying plate	.90
Total cost	$4.05

The chemicals listed here will be sufficient to develop many rolls of film and to print several hundred prints. This list does not, of course, include all possible equipment. However, it is sufficient for the beginner and can be added to at any time.

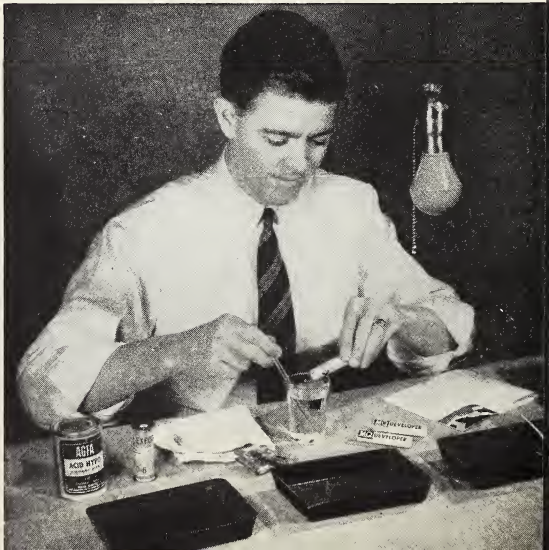
Developing a negative. Before shutting out all light in the darkroom, it is first advisable to get all your equipment and solutions ready for development. The trays should be arranged as follows:

Clean water	*Developing solution*	*Clean water*	*Fixing solution*

Mix the developing solution with water in the proportion recommended so that you have about 8 ounces of the mixture. Do the same with the fixing solution. It is important that the temperature of these solutions and the water be between 65° F and 70° F. This temperature will be assured if the solutions and the water have stood for a considerable time in a room which has this temperature. After the solutions and the water have been placed in the proper trays, you may exclude all light and turn on the red safety light, which should not be closer to the developing tray than two feet. Unroll the exposed film and remove the outside paper. Grasp the film at the ends and, with the emulsion side down, move it up and down in the water tray until the film becomes soft and pliable. The film is now ready to be placed in the developer. Continue the same action, moving the film up and down, in the developer tray for from five to six minutes or the time which is recommended for the developer you are using. It is essential that the strip of film be kept in constant motion in the developer. You may look at it every few minutes by bringing it near the safety lamp. Remove the film from the developer when the image seems to be clearest against its milky background. Then wash carefully in the water and transfer it to the fixing bath. While in the fixing bath, the film should be agitated every few minutes until the milky appearance disappears and the image becomes clear. It should be in the fixing bath at least twenty minutes. During the

It is not necessary to go to great expense in equipping a darkroom. Good-quality negatives and prints may be developed with the equipment shown here

Photographed on Agfa film



A film tank is often used for developing films

entire process, care should be taken not to scar the emulsion with the fingernails.

The negative is now ready for washing. It should be washed in running water for at least thirty minutes. After washing, the film should be hung up to dry. This can be done either with regular photographic clips or with clothespins. After drying, the negative should be cut apart with scissors. The individual negatives are now ready for printing.

Film can be more reliably developed by the use of a film-developing tank, although this adds to the cost of the equipment. Some amateur photographers prefer to have their negatives developed by a commercial photography company and concentrate their efforts on making prints.

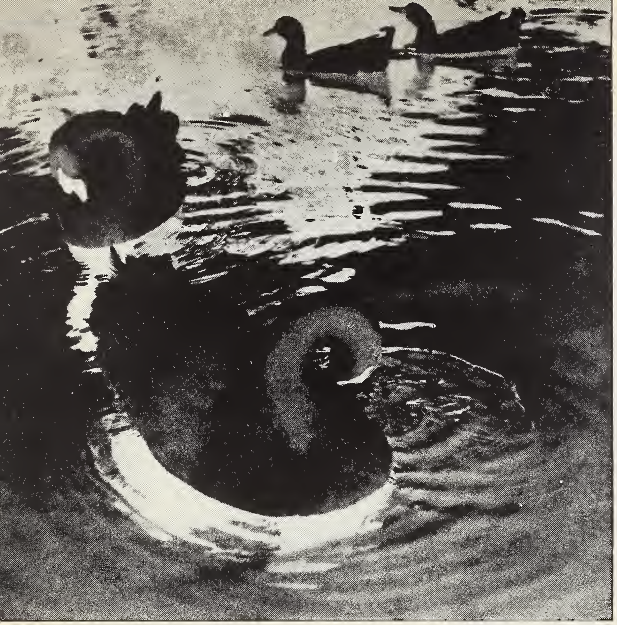
Chemical action in developing. Some of the chemicals used in the developers are pyrogallic acid ($C_6H_3(OH)_3$), elon, hydroquinone ($C_6H_6O_2$), and metol. They are essentially reducing agents. When the film is placed in a solution of these developers, the reducing agents continue the reduction of silver bromide which was started when the film was exposed at the time that the picture was taken. This reduction continues in the same proportions in which it was started until the silver subbromide is reduced to free black silver, which adheres to the celluloid film. In the negative on page 288 you will notice that the picture of the swan shows a considerable deposit of free silver. This is due to the fact that the swan's white feathers reflected a great amount of light to the film in the camera, which caused a large amount of the silver bromide to be reduced to silver subbromide. When the film was developed, this silver subbromide was reduced to a heavy deposit of free silver. Because the water was relatively dark it reflected very little light to the film; consequently very little silver bromide was reduced to silver subbromide, and when the film was developed very little free silver was deposited on this part of the film.

Fixing the negative. The chemical used in fixing is called hypo. Its chemical name is sodium thiosulfate, and its formula is $Na_2S_2O_3 \cdot 5\,H_2O$. The solution of this compound dissolves the unaffected silver bromide and any silver subbromide which has not been reduced in the developing solution. If the unaffected silver bromide is not removed from the film, it will turn black when exposed to light, and the negative will be ruined.

Printing. The arrangement of the trays for printing is the same as for developing. The same solutions can be used as for developing, but they are generally diluted in different proportions. The dilution for printing will be found on the cartons containing the developing and fixing powders.

You will notice that one side of the negative is shiny and the other is dull. The dull side is the emulsion side. In print paper the emulsion side is glossy. The emulsion side is the one which contains the light-sensitive salts suspended in gelatin.

When you are ready to start the printing, first see that all light except the safety light is excluded.



Photographed on Agfa film

This is a photograph of a negative. The deposit of silver on the film is in proportion to the amount of light reflected from the subject

Then place the emulsion side of the negative which you are going to print against the glass top of the printing box so that it covers the mask. Then, with the emulsion side down, place the print paper on top of the negative. Adjust the edges so that they are even. If the mask is the proper size, both the negative and the print will extend over the black strips of the mask, forming a border when the print is developed. Now turn the switch and count to three slowly and then turn off the switch. Remove the print paper and immerse it in the developing solution, being sure that the solution completely covers the paper. Agitate the paper, and, in a few seconds, you will see the image begin to appear faintly. When the image becomes distinct and clear, which usually takes from forty to sixty seconds, remove the print and wash it thoroughly in the tray of water. Then place it in the hypo and allow it to remain there for fifteen minutes, remove it, and wash it in running water for at least thirty minutes. When prints are taken out of the water, they should be placed face down on the clean chromium or ferrotype plates and covered with paper toweling. Then, using a toy rolling pin, roll out as much water as possible. The prints will then adhere closely to the plate. In from fifteen to sixty minutes the prints will "pop off" the plate, and, if immediately pressed between the pages of a book, they will not have a curl. Finally, trim the prints so that the borders will be even.

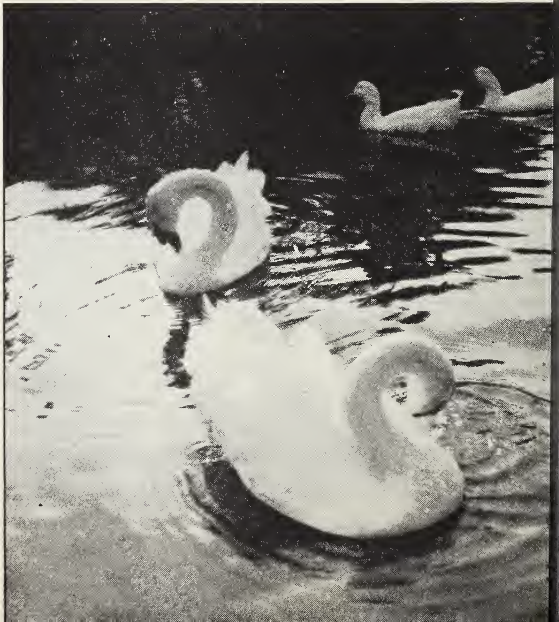
You will learn many ways of varying and improving these processes through experience. The exposure time must vary with the density and the contrast of the black and the white of the negatives. Some negatives require only one-second exposure, while others may require twenty or thirty seconds. Experimentation will teach you how long to expose any negative.

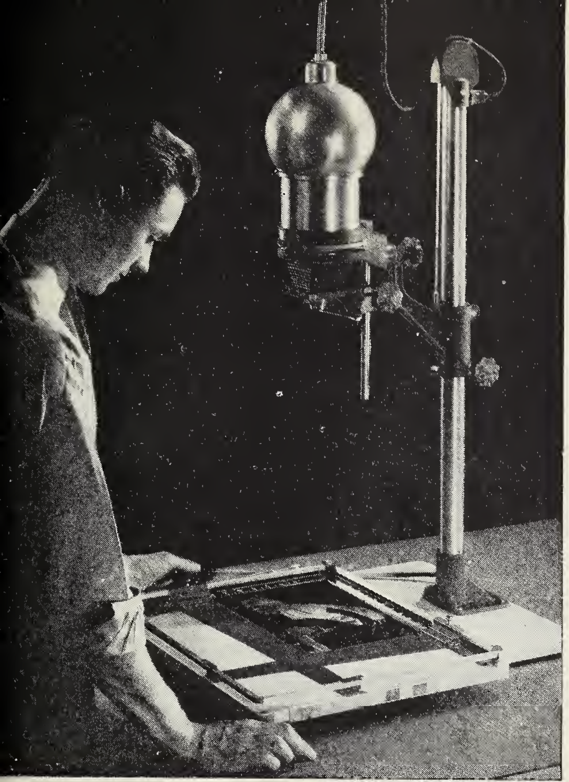
The chemistry of print-developing. When the print paper is exposed to the light which passes through the negative, the same action takes place as when the film was exposed in the camera. The emulsion on the print paper contains the same chemicals which were on the film. The light causes the silver bromide to be reduced to silver subbromide in proportion to the amount of light which passes through the negative.

When the exposed print paper is developed, the developing solution, which may be the same as that used to develop the negative, continues the reduction of the affected silver salts to free silver. The

This picture is the positive print made from the negative shown above. The deposit of silver (black) on the print is the reverse of that on the negative

Photographed on Agfa film





Eastman Kodak Company

Making an enlargement with a precision enlarger. How can a less expensive enlarger be made?

fixing solution has the same function as it had for the negative.

Bear in mind that the precipitation of silver on the negative produces an effect which, in one respect, is the reverse of the actual picture taken; that is, white on the original picture is black on the negative and vice versa. When the print of the negative is made, a picture of the negative is taken which gives us again the original white and black.

Enlarging. The popularity of small cameras has made enlarging more common than it was several years ago. Prints made by enlarging may become as common as prints made by direct contact.

An enlarger is not a complicated piece of apparatus. It may be bought ready to use, or you can very easily make one if you have a camera with a fairly good lens. The picture above illustrates the construction of an enlarger.

The light passes through the negative, carrying the image of the negative through the lens. The lens magnifies the image, which is focused upon the print paper. The focusing is done by regulating the distance between the lens and the print paper. When exposed for the correct amount of time, the print paper is removed and developed as has been previously described. A special type of paper called bromide paper, which is faster than ordinary print paper, is used.

Toning of prints. The toning of pictures has proved to be very interesting to many who follow photography as a hobby. The most effective tone is brown, or sepia, but it is also possible to obtain reddish, blue, and green tones.

The most common method of toning is that of bleaching out the black and white image of the print and then redeveloping in a solution which will provide the desired tone. You may obtain information as to how this is done and what solutions to use by reading some of the books listed in the references at the end of this problem.

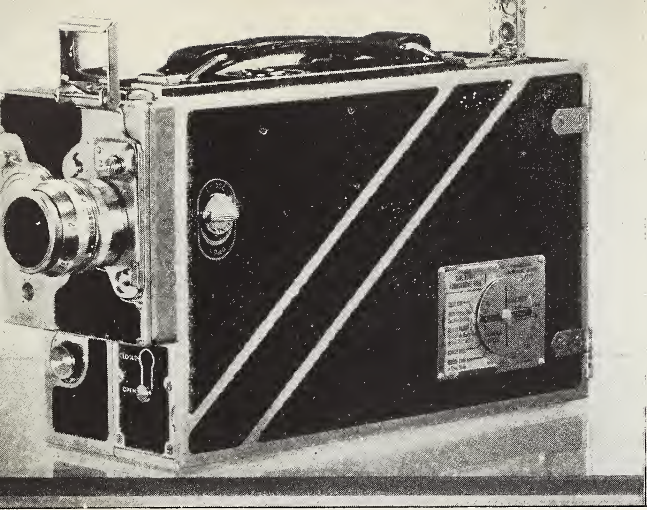
Motion pictures. The introduction of the 16-millimeter film has caused a considerable increase in the popularity of motion-picture photography as a hobby. In recent years the 8-millimeter camera has been introduced; and although it is probably not as efficient as the 16-millimeter camera, it has reduced the cost so that those of moderate means can afford to pursue the hobby.

The least expensive motion-picture camera which can be used successfully costs about $30. The film may range from $2 per 100 feet (about a three-minute showing) for black and white to $7.50 per 100 feet for color film. This cost includes the development of the film and making the positive ready for projection. After the shots have been taken and the film processed, it is necessary to have a projector to show the film. The total cost is much greater than for taking still pictures.

The first motion pictures taken by an amateur are usually disappointing because they do not have professional polish. However, many amateurs soon learn to improve the quality and make-up of their pictures.

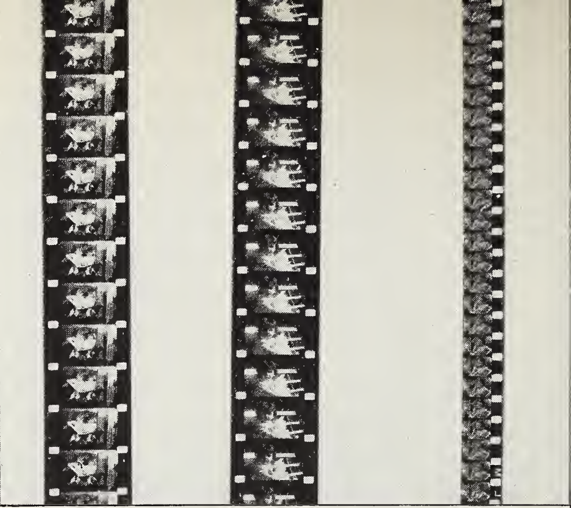
The film positive deteriorates as it is used. It must be kept moist, in a humidor; otherwise it will become brittle and crack.

If you can afford it, the making and projecting of motion pictures is an enjoyable hobby.



Eastman Kodak Company

A finer-type precision 16-millimeter movie camera



Eastman Kodak Company

The film on the left was taken with a 16-millimeter camera, and that on the right was taken with an 8-millimeter camera

The varied possibilities of photography as a hobby. There is no limit to what you can do in working with photography. This fact was well put by one photography enthusiast when he said, "The minute you feel that you have completely explored photography, someone has discovered something new and different that can be done."

An innovation which is gaining in popularity by leaps and bounds is color photography. It is now possible to take colored pictures with almost any camera which has a fast enough lens. The companies which sell the film also do the processing, which consists in developing the colored image in the film. Also, it is now possible to have colored prints made. Early in 1942 a new process of making colored prints was announced by the Eastman Kodak Company. The film from which these prints are made is processed so that a transparent colored negative may be developed from it. The colors in the negative are complementary to the colors in nature. Thus a green tree is red in the negative, a red hat is blue, and a blue suit is yellow. The negative is printed on specially processed paper which, when developed, is imprinted with the original natural colors. This new process will probably serve to stimulate the activity of amateurs who have already tried the more complicated processes of making colored prints; and this, together with the new converts who may be expected, will soon cause colored prints to become as common as colored film is at present.

The opportunity for artistic expression in photography is ever present. Many persons have had, in taking pictures, their first opportunity to develop creative artistic ability. Anyone can snap the shutter of a camera, but not everyone can obtain an artistic result. Other opportunities for creative expression are possible in the retouching and tinting of photographs.

The hobby of photography may be a means through which many friends are made. Others who are interested in photography will be anxious to exchange ideas with you, and you will have much in common to discuss with them. In almost every community and in many schools, photography clubs will give you an opportunity of sharing with others your interest in photography.

Your interest in amateur photography may lead you into a vocation concerned with photography. Many hobbyists have begun a small business of developing, printing, and enlarging for their friends and have soon found that it has led to a permanent vocation. Many of those who are working as portrait photographers, photoengravers, X-ray photographers, newspaper photographers, aviation photographers, and motion-picture cameramen got their start as amateur photographers.

EXERCISES

1. What are the values of having a hobby?

2. What are some hobbies which are related to chemistry?

3. List the ways in which photography has increased our joy of living.

4. What are the essential parts of a camera?

5. Explain what is meant by the speed of a shutter.

6. Show how the f value of a lens is computed.

7. What is the reason for having a lens with a relatively low f value? Why is it undesirable for an amateur to have a lens of too low an f value?

8. What qualities of films and print paper are sold in your community by different companies?

9. Explain in detail what happens to the film when a picture is taken.

10. What substances are on an unexposed negative or piece of print paper?

11. What substances are used in developing negatives or prints?

12. Explain, using diagrams, how you would set up your own darkroom to develop and print pictures.

13. What is meant by the term *fixing* as applied to a negative?

14. How does an enlarger make pictures larger?

15. What are some possibilities of photography as a hobby?

REFERENCES

Crabtree, J. I., and Matthews, G. E. *Photographic Chemicals and Solutions.* American Photographic Publishing Company, Boston, 1939.

Croy, O. R. *The Secrets of Trick Photography.* American Photographic Publishing Company, Boston, 1937.

Deschin, Jacob. *Making Pictures with the Miniature Camera.* McGraw-Hill Book Company, Inc., New York, 1937.

Doring, W. H. *Lifelike Portraiture with Your Camera.* American Photographic Publishing Company, Boston, 1939.

Feininger, Andreas. *New Paths in Photography.* American Photographic Publishing Company, Boston, 1939.

Henney, Keith. *Color Photography for the Amateur.* McGraw-Hill Book Company, Inc., New York, 1938.

Jordan, F. I. *Photographic Enlarging.* Folmer Graflex Corporation, 154 Clarissa Street, Rochester, New York, 1938.

Lambert, A. R. *The Photographic Buyers' Handbook.* Simon and Schuster, Inc., New York, 1939.

Lawrence, E. *Build It Yourself: Enlargers and Enlarging Accessories.* Galleon Publishers, Inc., New York, 1938.

Mees, C. E. K. *The Fundamentals of Photography.* Eastman Kodak Company, Rochester, New York, 1935.

Mortensen, William. *Command to Look.* Camera Craft, 425 Bush Street, San Francisco, 1937.

Mortensen, William. *Print Finishing.* Camera Craft, 425 Bush Street, San Francisco, 1938.

Natkin, Marcel. *Fascinating Fakes in Photography.* Camera Craft, 425 Bush Street, San Francisco, 1939.

Neblette, C. B., Brehm, Frederick W., and Priest, Everett L. *Elementary Photography.* The Macmillan Company, New York, 1938.

Peck, A. P. *So You Want to Take Better Pictures.* Scientific American Publishing Company, New York, 1939.

Simon, R. L. *Miniature Photography.* Simon and Schuster, Inc., New York, 1937.

Elementary Photographic Chemistry. Eastman Kodak Company, Rochester, New York, 1936.

How to Make Good Movies. Eastman Kodak Company, 343 State Street, Rochester, New York, 1938.

How to Make Good Pictures. Eastman Kodak Company, Rochester, New York, 1939.

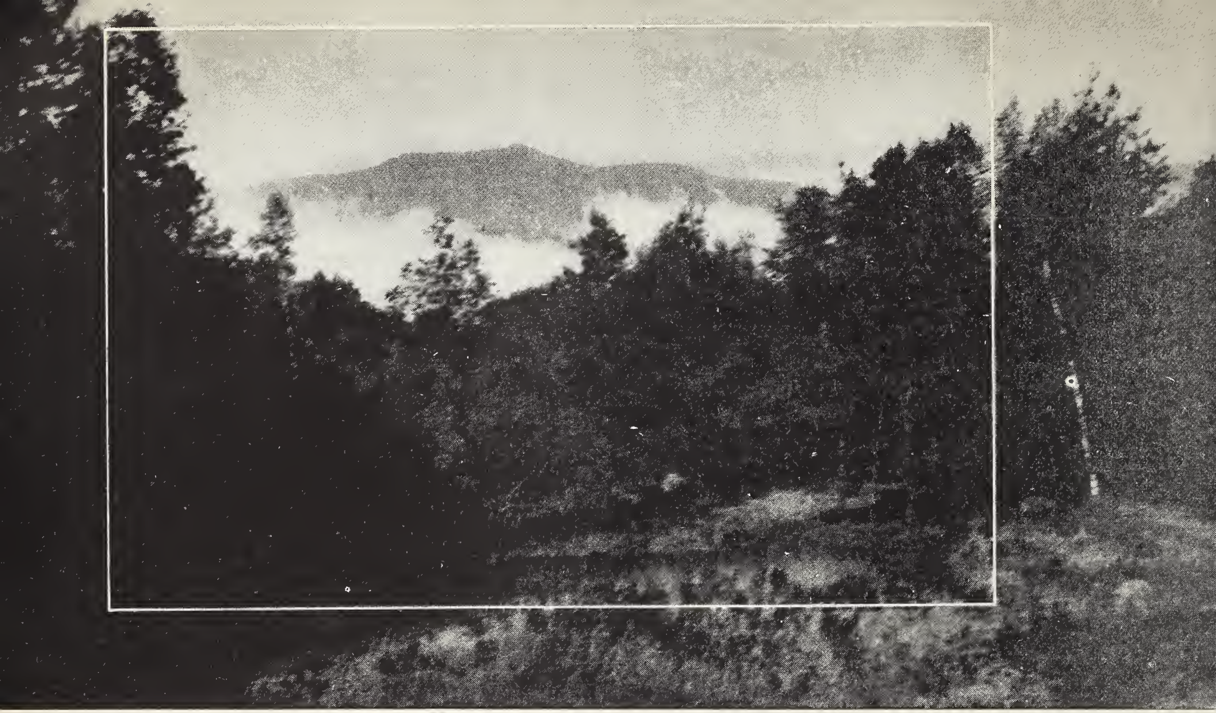
Problem 2. How can I pursue other hobbies which involve chemistry?

Try a hobby. Much of the joy of pursuing a hobby comes from trial-and-error experience in developing the hobby. The discussion of photography has given you an insight into the possibilities of a hobby. It is impossible to discuss fully all the hobbies that are listed at the beginning of this unit. However, some of the possibilities of each hobby are indicated with the hope that you will select and pursue at least one of them.

The home laboratory. The regular experiments which you have performed or have seen performed in the laboratory may have stimulated you to further experimentation. A home laboratory, with your own equipment and chemicals, will provide many hours of enjoyment for you. With a home laboratory you will have an opportunity to study more advanced chemistry if you feel the urge to do so. Your interest may be directed to the more spectacular experiments, such as those involving color changes and the making of chemical gardens and Fourth of July "snakes." You may want to perform many practical experiments, such as testing fabrics and testing foods for adulterants and harmful ingredients. In addition, the making of useful products, such as cosmetics, dentifrices, and paints and varnishes, may appeal to you.

REFERENCES

Hiscox, G. D. (Editor). *Henley's Twentieth Century Formulas, Recipes, and Processes.* Norman W. Henley Publishing Company, New York, 1930.



Artistry in photography should be cultivated. In this picture a point of view including only the section outlined in white would have made a much more artistic picture

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Lynde, John Carleton. *Science Experiments with Home Equipment.* International Textbook Company, Scranton, Pennsylvania, 1937. See also other books by this author.

The Home Chemist. Popular Science Publishing Company, Inc., New York, 1934.

"Home Laboratory Chemistry," a regular feature of *Popular Science Monthly.*

Collection of minerals. The formation and evolution of the earth's crust has produced many strange combinations of the elements. Many minerals found in the crust of the earth are beautiful, and it is natural for anyone to pick up and keep mineral specimens which are pleasing to the eye. For this reason, the collection of minerals is one of the oldest hobbies.

There are thousands of mineral collectors in this and other countries. If you live in a region which is mountainous, you have a collector's paradise at your back door. If you live where specimens are scarce, you will find that they can be bought very reasonably or that exchanges may be made with collectors who live in other regions.

The classification and mounting of mineral specimens are both educational and enjoyable. You will find much information about these activities. Do not fail to get in touch with those in your school who are collecting minerals. They can give you much valuable help.

REFERENCES

English, G. L. *Getting Acquainted with Minerals.* McGraw-Hill Book Company, Inc., New York, 1934.

Hawkins, Alfred C. *Book of Minerals.* John Wiley & Sons, Inc., New York, 1935.

Zodak, Peter. *How to Collect Minerals.* Rocks and Minerals, Peekskill, New York, 1934.

Crime detection. The Federal Bureau of Investigation and many other agencies, private and municipal, for the detection of crime have made great strides in adapting the science of chemistry to the detection of crime. Through the use of chemistry, it is now possible to run down criminals who otherwise might remain undetected.

Chemists have discovered a substance which can be used to take fingerprints accurately from metal

Ewing Galloway

Mineral-collecting is a fascinating hobby. This young man is studying a specimen from his collection

or wood. They have found methods of detecting human blood, whether fresh or old and dried. The microscope has been used to identify fabrics, hair, and dust particles, whose identification is often necessary to fix the blame for a crime. Chemistry has made it possible to discover whether a person has fired a gun within a given time. Tests for intoxication are becoming more accurate. The chemist is frequently called in to make tissue and stomach tests to aid in determining the cause of death.

Because of the great interest that young people have in crime detection, many are following it as a hobby.

REFERENCES

Crump, Irving, and Newton, John Walter. *Our G Men.* Dodd, Mead and Company, New York, 1937.

Robinson, H. M. *Science versus Crime.* The Bobbs-Merrill Company, New York, 1935.

Etching. This hobby will appeal to anyone who is interested not only in chemistry but also in art. Chemicals are essential for etching, but the beauty of objects that are etched depends upon how artistic the design is.

Etching is usually carried on with glass or metal. When either of these materials is etched, it is almost always done to produce a useful article. This makes etching a practical hobby.

The etching of glassware during the past fifteen years has been improved so much that hand cutting of the design is now restricted to the more expensive glassware. The amateur can now come very close to duplicating professional etching of glassware.

The etching of designs on metals requires considerable skill in shaping the metal into such articles as book ends, plaques, bowls, dishes, and many other useful metal things. Such articles, in many cases, may be greatly beautified by an etched design. Almost all metal can be etched, and the chemical part of such etching is very simple.

REFERENCES

Baxter, William T. *Jewelry, Gem Cutting, and Metalcraft.* McGraw-Hill Book Company, Inc., New York, 1938.

Lutz, E. G. *Practical Engraving and Etching.* Charles Scribner's Sons, New York, 1933.

Mullen, J. B. "Etching Glass and Metal," *Popular Mechanics*, February, 1938.

Smith, Robert E. *Units in Etching, Spinning, Raising, and Tooling Metal.* The McCormick-Mathers Publishing Company, Wichita, Kansas, 1939.

Stieri, E. *Book of Indoor Hobbies.* McGraw-Hill Book Company, Inc., New York, 1939.

Taking fingerprints from the door of a safe

Ewing Galloway

Ewing Galloway

A new world of beauty may be opened through crystal microscopy

Wailes, R. B. "Thrilling Stunts with a Glass-Eating Chemical," *Popular Science*, January, 1938.

"Simplified Glass Etching: Drawings and Instruction," *School Arts*, December, 1938.

Chemical microscopy. The use of the microscope offers a very interesting possibility for one who is searching for a hobby. Almost everyone is curious to see things that cannot be seen with the naked eye. Many persons have had little opportunity to do so.

The hobby of chemical microscopy necessitates a microscope, which may be expensive. It is possible for the beginner to secure a microscope for less than $5. Such an instrument will not compare with those that are in your school, but it will serve you well until you discover whether you are interested enough to continue. It may be possible for you to use a school microscope if you carry on your hobby within the building.

There are many things that can be done with a microscope. The study of the crystals of chemical compounds and the growth of crystals is fascinating. Fabrics can be studied to determine the kinds of fibers from which they are made; the fineness of face powders can be discovered; and the sharpness of the particles of tooth paste will be revealed.

One who has a microscope soon becomes enthralled by the study of microscopic plant and animal life. Microphotographs of all descriptions may be made.

REFERENCES

Beavis, Gerald. *Book of the Microscope.* J. B. Lippincott Company, New York, 1931.

Watson-Baker, W. *World beneath the Microscope.* Studio Publications, New York, 1935.

Wells, A. L. *The Microscope Made Easy.* Frederick Warne & Co., Inc., New York, 1938.

Wood, J. G. *Common Objects of the Microscope.* David McKay Company, Philadelphia, 1939.

Yates, R. F. *Exploring with the Microscope.* D. Appleton-Century Company, Inc., New York, 1934.

Making useful products in the home. There are many products that are used in the home which can be made in the home. The hobby of home manufacturing is not only an interesting one but also a profitable one. Almost all the products which can be made by the amateur will equal the quality of the commercial products and can be made much more cheaply. Most products can be manufactured with the equipment found in the ordinary kitchen.

Such products as hand lotions, face creams and powders, furniture polish, cleaning solutions, and silver polish can be made with very little difficulty.

REFERENCES

Bennett, H. *The Chemical Formulary.* D. Van Nostrand Company, Inc., New York, 1935.

Chilson, Francis. *Modern Cosmetics.* The Drug and Cosmetic Industry, New York, 1934.

Wellman, Katharine. *Beauty Begins at Home.* Covici, Friede, Inc., New York, 1936.

Electroplating. Coating an inexpensive metal with a more expensive metal is a common practice in industry. The base metal in such cases is always a cheaper metal than the covering metal. Thus copper is often the base metal of a gold-plated ring, and iron the base metal of silver-plated tableware. The plating is done by electricity.

Electroplating is a very practical hobby because one usually plates something that is useful. Many articles in the home may be renewed by electroplating. Old silver-plated trays, silverware of all kinds, and nickelware may be reclaimed by replating them. Through the process of electroplating, it is now possible to plate almost anything, even wood and statuary. Many articles that we use appear to be made of pure copper, zinc, chromium, silver, or gold. In reality, they are plated with these.

REFERENCES

Barkes, G. "Practical Electroplating Unit for the School Shop," *Industrial Arts and Vocational Education*, February, 1937.

Crowley, C. A. "Electroplating with Gold and Silver," *Popular Mechanics*, September, 1932.

Crowley, C. A. "Electroplating with Lead, Zinc, and Cadmium," *Popular Mechanics*, November, 1933.

Smith, Robert E. *Units in Etching, Spinning, Raising, and Tooling Metal.* The McCormick-Mathers Publishing Company, Wichita, Kansas, 1939.

Reed, W. B. "How to Copperplate Wood," *Popular Science*, July, 1940.

Wailes, R. B. "Electroplating in Your Own Laboratory," *Popular Science*, February, 1934.

Waring, R. G. "Plating Gray-Iron Book Ends: Formula for Bronze Finish," *Industrial Arts and Vocational Education*, November, 1936.

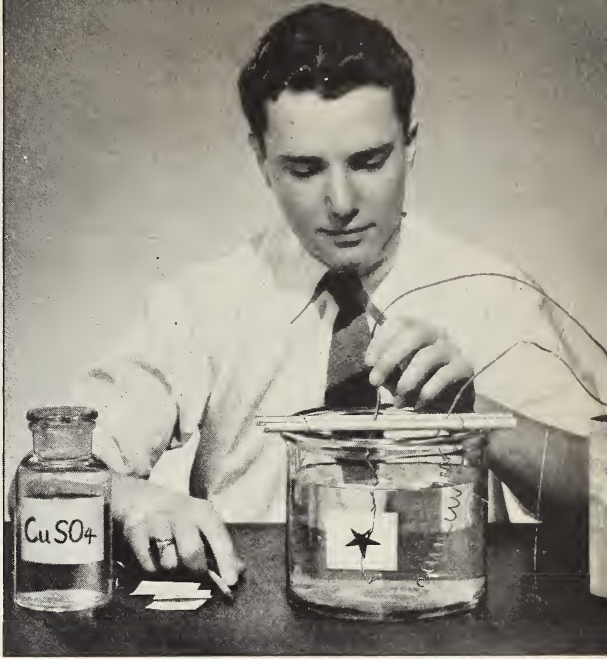
Yates, R. F. "Aluminum Can Be Plated: Travers Process," *Scientific American*, July, 1938.

Soilless culture of plants. Soilless culture, also called chemi-culture or hydroponics, has come into wide use during the past few years. In fact, it has already reached the stage where it is used in the commercial production of many plants. Before the entry of the United States into the second World War, soilless culture had been started at Wake Island to produce fresh vegetables for those who crossed the Pacific Ocean in hydroplanes.

Soilless culture is carried on in tanks or vessels. Water containing the proper chemicals in the correct proportions is placed in these tanks. These chemicals are essential to the growth and culture of the plants being propagated.

Plants produced by chemi-culture grow larger and yield more. In addition, the quality is improved, foods have a higher percentage of minerals, and flowers have a more beautiful color.

Soilless culture is one of the fastest-growing hobbies. A person interested in producing and experimenting with plants will find that this method makes possible year-round activity. Every activity connected with this hobby can be carried on in the home. The equipment is simple to make, and the chemicals are inexpensive.



Ewing Galloway

Depositing copper from copper sulfate. The wire from the negative terminal of a dry cell contacts the drawing of a star made with the graphite from a soft pencil. The positive terminal connects with a bare copper wire in the copper sulfate solution [1]

REFERENCES

Connors, C. H., and Tiedjens, V. A. *Chemical Gardening for the Amateur.* Wm. H. Wise & Company, New York, 1939.

Ellis, Carleton. *Soilless Growth of Plants.* Reinhold Publishing Corporation, New York, 1938.

Matlin, D. R. *Growing Plants without Soil.* Chemical Publishing Company, Inc., New York, 1939.

EXERCISES

1. Select two or more of the hobbies which have been described and tell briefly how each may be pursued.
2. What values do you think the pursuit of the hobbies that you have described might bring?
3. Are tomatoes grown by soilless culture different from those grown in soil?
4. What substances may be made in a home laboratory?

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[1] Adapted from an experiment in Caldwell and Curtis's *Science for Today*, suggested by Dr. W. A. Gorton.

FURTHER ACTIVITIES FOR HOBBYISTS

1. A very interesting and valuable project that can be sponsored by your class is a hobby night. All pupils in the school should be invited to display their hobbies. Invite your parents and others in the community. A successful hobby night takes a good deal of careful planning.

2. If a few in the class are interested in photography, they can form the nucleus of a camera club. A well-organized club will provide you with many enjoyable and profitable moments in developing and printing pictures of your own and pictures for the school. Another project which the club could profitably pursue would be the study of all types of cameras. The kinds of lenses, shutters, and supplementary equipment might well require several meetings to study thoroughly.

3. Have each pupil who has an interesting hobby present it to the class.

4. Form a committee of students who are hobby enthusiasts. Have this committee organize a discussion of the topic "What a Hobby Has Meant to Me."

5. Each pupil who pursues one of the hobbies mentioned in this unit should be encouraged to give a report of progress at least once every six weeks.

UNIT EXERCISES

Each statement which follows may be completed in one or more ways. On a separate sheet of paper write the letter or letters which indicate the correct way or ways of completing each statement. Do not write in this book.

1. The selection and pursuit of a hobby will do the following things: (*a*) make one rich (*b*) satisfy one's natural urge to create something (*c*) make one a more interesting person to talk with (*d*) provide an enjoyable way to utilize leisure time (*e*) increase the tendency to commit crimes.

2. The number of hours per day which are free for most people are (*a*) one (*b*) five (*c*) one-half (*d*) three (*e*) two.

3. Hobbies which are closely related to chemistry are (*a*) stamp-collecting (*b*) home workshop (*c*) home laboratory (*d*) hydroponics (*e*) photography.

4. Chemical substances used in photography are (*a*) hypo, or $Na_2S_2O_3 \cdot 5\,H_2O$ (*b*) acetic acid, or CH_3COOH (*c*) $AgBr$ (*d*) "Jello" (*e*) hydroquinone.

5. From the viewpoint of making good pictures the most important parts of a camera are (*a*) the camera box (*b*) the lens (*c*) the shutter (*d*) a very "fast" film (*e*) a view-finder.

6. The chemical processes involved in taking a picture are (*a*) reduction of silver salts (*b*) oxidation of silver salts (*c*) hydrogenation (*d*) catalytic (*e*) photosynthesis.

7. In developing a negative, which of the following operations should be performed and in what order? (*a*) Putting negative in fixing solution (*b*) washing for thirty minutes in running water (*c*) moving the film up and down in the water tray to soften it (*d*) moving the film in the developing solution for the recommended time (*e*) turning on the red light (*f*) putting developed film in wash water.

8. The following materials are relatively easy to make in the home laboratory: (*a*) white lead paint (*b*) cold cream (*c*) tooth paste (*d*) delicately blown glassware (*e*) plastics.

9. Growing plants and vegetables in soilless tanks is a desirable way of plant propagation because (*a*) more food can be grown in a small area (*b*) different plants can be produced by this method (*c*) plants may be given exact amounts of minerals by this method (*d*) plants may be kept free of insects (*e*) plants produced by this method grow larger and yield more.

UNIT 19

Vocations Related to Chemistry

Fortunate indeed is the man or woman who can say, "I would rather be doing my job than any other of which I know." If one can choose his life vocation early and then plan his future course toward fitting himself for that work, his chances of success will be greatly enhanced. The choosing of one's lifework is of such importance that each boy and girl should give a great deal of thought and study to it as early in life as possible.

Not all high-school graduates will or should go to college. Though some graduates will be able to choose a vocation which is to their liking, many will be forced to take any job available. Many high-school students are thinking about their lifework only in terms of professional occupations. Statistics show that fewer than 20 per cent of all the vocations require more than a few weeks of training. Among this 20 per cent are the professions. On the other hand, about 80 per cent of the available jobs require little or no previous training. These facts indicate that only a small minority of students will be able to enter the professions or other occupations which require specialized training. Therefore more and more of the graduates from high schools will have to find work in vocations that require little or no previous specialized training.

It behooves every student to attempt conscientiously to find a vocation which meets his qualifications and one in which he can be successful and happy. Once he enters a certain type of work, he should seek to excel in that work. The bookkeeper, the clerk, or the bricklayer who does his work well will soon be recognized because of his ability. His work should be considered as essential to modern-day living as any other kind of work. The study of one's work, the striving toward greater perfection, no matter what the job, will bring a feeling of satisfaction, which is the real measure of one's success.

The work of the chemist is interesting but exacting

Allis-Chalmers Company

If, after entering a certain type of work, one finds that he is not fitted for that kind of work and is unhappy in it, he should, nevertheless, work just as hard to give satisfaction and, in the meantime, keep looking and preparing for a more desirable type of job.

Few of your class will enter any of the vocations related to chemistry. However, every boy and girl in the class is probably thinking a great deal about what he will do after school days are over. The purpose of this unit is not primarily to interest you in the vocations related to chemistry, but rather to help you to make a vocational plan of your own.

In the study of vocations, you must understand that there is no royal road to success. Only by hard work, constant study of the job, preparation for the job ahead, and the ability to get along with your associates and others with whom you come in contact can you make a success in any field of endeavor. As your responsibilities in any job increase, problems requiring decisions will also increase. Much of your success will depend on your ability to make the right decision whenever confronted with a problem.

You have been given training in this course in the solving of problems scientifically. The problem of selecting a vocation is one of the most important to be solved during your life. Attack this great problem scientifically.

PURPOSES TO BE ACHIEVED

1. To aid you in developing a technique of vocational investigation.
2. To help you to make a vocational plan of your own.
3. To acquaint you with the vocations related to chemistry.

PROBLEMS TO BE SOLVED

1. How can I make a wise choice of my lifework?
2. What should I know about the vocations related to chemistry?

Problem 1. How can I make a wise choice of my lifework?

Wise and early choice of a vocation promotes happiness and success. Unfortunately, few people who are working have used the scientific method of finding the vocation or vocations to which they are best suited. For this reason, many persons are working at occupations in which they have no interest. Such occupations are drudgery to these persons, and their work is merely a means of earning a living. People who cannot become adjusted to their vocation cannot expect to obtain a full enjoyment of life, and in many cases they are genuinely unhappy.

When you consider the method used by many persons in selecting their lifework, it is easy to understand why there are so many misfits. The eager desires of fond parents very often have been responsible for the selection. Greed for money or the glamorous nature of the work has guided the choice of large numbers of people. These and many other reasons which could be given can hardly be considered scientific.

The choice of a vocation is undoubtedly one of the most important decisions that you must make. It is so paramount in your life that you should do everything that is humanly possible to find the job or jobs to which you are best suited and in which you can be successful. To do this requires a great amount of time and energy. You should proceed according to such a plan as this:

1. Make a list of vocations which you *feel* you are interested in. You may obtain many suggestions for this list by reading some of the references given at the end of this unit. You may also be aided by taking a vocational-interest locator test (a test which will indicate the areas within which your interests fall) and by talking to your counselors and others who are interested in the vocational future of boys and girls.

2. You should then decide what is important for you to know about each of these occupations. A list of questions about jobs can be formulated with the help of your classmates. For each job that you have listed, these questions should be answered by thoroughly investigating all literature available and by interviewing men and women who are engaged in the occupation. You will want to know what preparation is necessary, what special aptitudes are required, and many other important facts about the occupation.

3. It is important that you check your personal qualifications, characteristics, and aptitudes against

those which are demanded by each of the vocations studied. You should make a personal analysis of yourself. Aid may be obtained in doing this by the use of personal inventories, personality tests, and aptitude tests. When this personal analysis is checked against the demands of each vocation, you will surely be able to discard some of the vocations as unsuitable.

4. It is advisable that you get a part-time job, preferably one which is closely related to the vocation of your choice. Psychologists tell us that we learn by doing. If you want to learn about vocations and the problems you have to face on the job, it is best to learn while working. There are so many part-time jobs which do not displace adult labor that every boy and girl can find one if he tries hard enough. With the aid of your class, make a list of such jobs, and you will be surprised to find how many are available.

5. In your senior year in high school or just before you go out to get a job, you should make a study of the important problems that you will have to face in obtaining a job and in working on the job. A list of these problems should be made by your class. Many such problems as these will be on your list:

How does one go about applying for a job?
What factors determine success?
Is it advisable to join a labor union?

6. The final step is to make a personal vocational plan. To do this, it will be necessary to use all the materials that you have studied and gathered. Apply all this information to yourself. On the basis of your investigation, you should be able to make an intelligent selection of from two to six occupations in which you may have an opportunity to succeed. Chart your future in each of these jobs. Begin where you are and plan as far ahead as you can visualize. Make these plans in detail. Finally, choose one plan and make the firm decision to follow it. Do not make the usual mistake of "drifting" for several years before you find your niche in the world's work.

Chemistry and your lifework. The program of vocational choice which has been outlined cannot be fully carried out in the chemistry class. Time would forbid it. However, one purpose of your work in chemistry should be that of learning about the vocations which are related to chemistry. In knowing about the chemical vocations, along with many other vocations, you will be better prepared to make your choices intelligently.

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Engineers are the men who put science to work. New industries are born and vast projects are planned when trained engineers get together to analyze problems, study scientific data, and explore possibilities

EXERCISES

1. Write your opinions on both sides of this question: Should all high-school graduates go to college?
2. What are the advantages of early planning of your lifework?
3. What factors are involved in making a vocational plan?
4. Briefly outline your own vocational plan.

Problem 2. What should I know about the vocations related to chemistry?

Many vocations are related to chemistry. The study of chemistry is so fascinating to some students that they may feel inclined to continue work in this field after graduation. Chemistry is involved in more kinds of work than most high-school students realize. If you are interested in chemistry as a lifework, there are many vocations involving chemistry from which you may make a choice. Though it is not possible to discuss all these vocations, a brief description of some of them should help you form more definite ideas about the future.

The chemist and the chemical engineer. There are many kinds of chemists; their jobs vary from routine laboratory testing to the creative work of the research chemist. In many industries it is possible to take a high-school graduate, preferably one having had some chemistry, and teach him to carry out a number of relatively simple analytical tests, such as determining the strength of solutions, finding the viscosity of lubricating oils, ascertaining the composition of coal, discovering the butterfat content of milk, and many other routine tests which, in a well-managed industry, are used to be sure of the purity of products. A person working in this capacity is sometimes known as a chemist but is more properly called a laboratory assistant. The salary for this work ranges from $12 to $18 per week at the beginning of employment and may reach $125 per month for more experienced workers. Any large manufacturing plant is a possible source of employment in jobs of this nature.

Many industries employ an experienced chemist to supervise the work of the laboratory assistants. It may be his responsibility to interpret the results of the tests and to see that the products of the plant maintain a high quality. His duty includes the analysis of raw materials and often a check upon the materials purchased by the plant. He may analyze the gases which come from the smokestack to see if the maximum fuel efficiency is being obtained. He may analyze the water which is used in the plant for hardness and determine the amount of chemicals necessary to soften the water.

Such a chemist is usually called a chemical engineer, since he must know the manufacturing processes and the operation of the machinery involved. He may even be called upon to devise new types of machinery or develop new processes.

A research chemist must be able to analyze materials and devise methods of purifying products. He may even synthesize new materials, determine their properties, and develop methods for economical production. He should be a man with vision, for it takes a dreamer as well as a scientist to produce a yellow plastic mass and see in it a comb or a pyroxylin vanity set.

There are over twenty branches of chemical engineering that one may study in college. A few of these are those having to do with petroleum, ceramics, cottonseed oil, dyes, brewing, food, fuel, cement, corn products, and plastics.

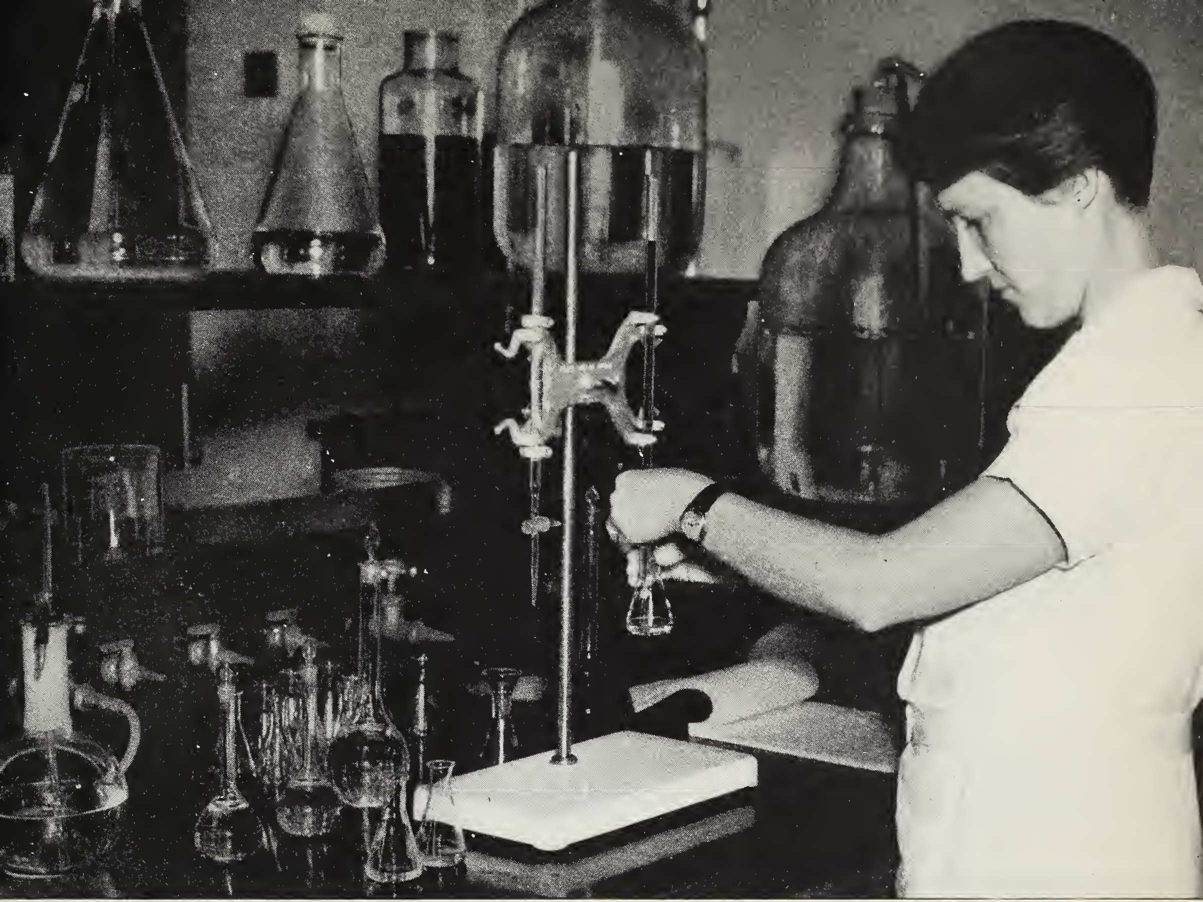
One interested in becoming a chemical engineer should take all the mathematics offered in high school, both physics and chemistry, and, if possible, either French or German. The foreign language is not always necessary, though it will be an aid if one does research work. Unless a student has ability above the average in the above-mentioned subjects, the field of chemical engineering should not be chosen.

A bachelor-of-science degree in chemistry or chemical engineering is granted upon the completion of four years of work in a university. If the student's work has been in chemical engineering, a fifth year of study in the chosen field of chemical engineering is advisable.

The Bureau of Labor Statistics of the United States Department of Labor states that about 17,000 chemical engineers were employed in the United States in 1934. Ten per cent of these earned about $1687 a year; 15 per cent earned up to $2539; 25 per cent earned up to $3804; another 25 per cent earned up to $6000; 15 per cent earned up to $9000; and 10 per cent earned in excess of $9000 a year. The average beginning salary of the chemical engineer is about $100 a month.

Many men who have graduated in chemical engineering, however, go into industrial plants in many other capacities than that of chemist. Because of their training, they should, as they gain experience, be able to occupy responsible positions.

The chemistry teacher. Another vocational field which includes all phases of chemistry is that of teaching the subject in high schools and colleges. The requirements for entering this field are much the same as those for chemical engineering. If you are contemplating going into this field or the related field of teaching any other science, you should take all the mathematics courses and as many science courses as possible while in high school. Moreover, you should receive grades above the average in all



Underwood & Underwood

The laboratory technician must have a knowledge of chemistry and biology. What is the nature of her work?

such courses. You should not have a strong dislike for any particular mathematics or science course and at the same time expect to teach science.

Four years of study in the area of science in which you expect to teach are required beyond high-school graduation. Many related sciences will also be studied. In addition, you will be required to take several courses in psychology, professional education, and student, or apprentice, teaching. High-school teaching requires a bachelor's or a master's degree, and most colleges require their teachers to have a doctor's degree. A doctor's degree requires three years of more or less specialized training beyond the bachelor's degree.

The salary range for chemistry or other science teaching in high schools is from $900 to $4000 a year, depending on the section of the country and the size of the school. The average salary for an experienced teacher is approximately $1600 a year. For college teaching the salary range is higher. A teacher of science in college will generally be allowed to teach exclusively in the field in which he has specialized, whereas in high school a science teacher may be asked to teach two or more different sciences.

The work of a teacher is pleasant and stimulating if he is interested in the growth and development of young people and has the qualities of patience and resourcefulness. The teacher of chemistry or any science should be strong, physically and mentally, and be able to stand the strain on the nervous system which all kinds of teaching produce. Considerable vacation time must be spent in continued study if success and growth are expected. The teaching of science offers opportunity for research on problems of special interest to the teacher.

Laboratory technician. This is a relatively new field open largely to women who have had biological and chemical training. The work required in this profession is found in hospital or clinic laboratories, doctors' offices, medical colleges, and health agencies. Such technicians may run bacterial counts and blood counts, make microscopic examinations, and run milk tests or water analyses. They often work in private commercial laboratories conducting tests for doctors unable to maintain their own laboratories.

Labor Department statistics show that about 12,000 women and a few men are employed in this profession. The pay is only fair, as this field of work is largely filled by untrained workers who received their training while in service. A trained worker in this field may average about $125 a month; a few, who rise to executive capacities, may earn up to $250 per month. Undoubtedly, as the demand for college-trained technicians increases, the salaries will increase.

The training for this work requires from two to four years, preferably in a school which has a special course of study for this profession. Such schools are often found in conjunction with a medical school. For the high-school student who plans to enter this vocation, it is advisable to take courses in biology, chemistry, mathematics, and possibly physics.

Assistants to doctors and dentists. These jobs are open to girl high-school graduates. The qualifications usually demanded are a pleasing personality and some knowledge of science and laboratory techniques. Applicants are usually expected to be proficient in stenographic and clerical work.

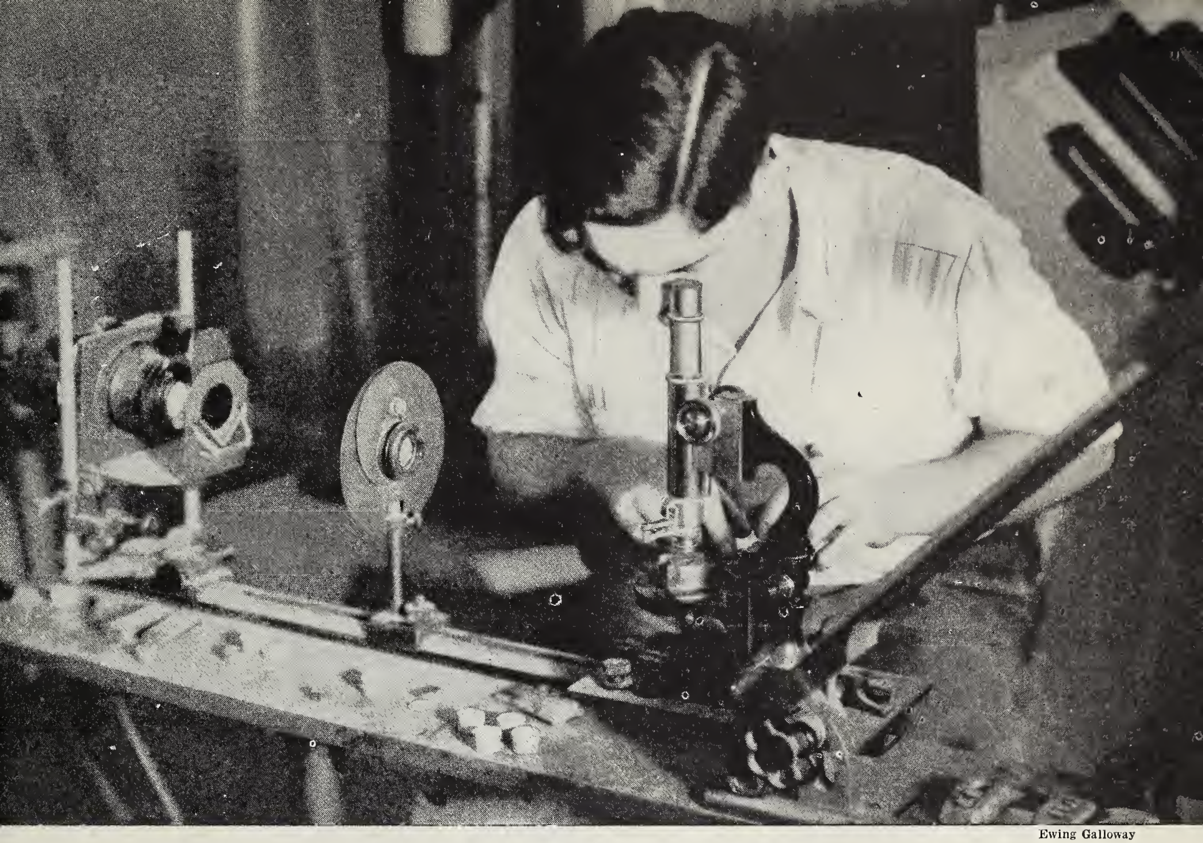
The work involves such activities as taking X-ray pictures, developing X-ray films and plates, making amalgams for teeth fillings, sterilizing instruments, assisting the doctor or dentist at work, and keeping a small laboratory or workroom neat and clean. In addition, a girl employed in this occupation must answer the telephone, make appointments, send out bills, keep accounts, and take care of the correspondence. The ability to meet people with natural friendliness is the most important requirement of the job.

The work is pleasant and interesting, but in many localities the pay is low. The beginning salary may be as low as $10 a week. Some experienced workers make as much as $30 a week.

The biochemist. The work of the biochemist deals with chemical compounds and processes occurring in plants and animals and with the influence of chemicals on the vital processes of living organisms. Therefore those specializing in this vocation should specialize not only in chemistry but also in biology and physiology, of plants as well as animals. At least five years of college work are desirable. Graduates often go into research and analytical work. Many find positions on the staffs of large medical schools and hospitals. Others establish laboratories where they specialize in clinical analyses for physicians. A large number find employment with the government in many of its scientific branches. The pay for this work starts at about $100 a month; experienced biochemists in governmental work receive as much as $4800 a year.

A metallurgist. It is the job of the metallurgical engineer to separate metals from their ores, refine them, and prepare them for use. He may work in a large plant, where his job is to see that a uniform product is being produced, to see that all operating processes are functioning properly, and to determine the quality of the product to meet the needs of other industries. He has specialized in inorganic chemistry, especially that having to do with the physical and chemical properties of metals and their method of production. Metallurgy offers many opportunities for research—for example, research leading to the making of new alloys and to the discovery of new processes for the extraction of low-grade ore. The metallurgist is a graduate of a mining or engineering college, with at least four years and, many times, five years of training. There are about 7500 such trained specialists in the United States, and the pay is somewhat higher than that of the chemical engineer. It is among the highest paid of the engineering professions, ranking with mining engineering.

Mining engineering. The training in college of the mining engineer is similar to that of the metallurgist. It requires a comprehensive study of geology and mineralogy, assaying, some civil engineering, and much chemistry. For some people this branch of engineering has a great fascination. The mining engineer is engaged in testing mineral deposits to determine their productive value. He devises efficient methods of extracting valuable metals from ores. Very often he plans and operates milling and



Ewing Galloway

This metallurgist is testing metal to determine its purity

smelting plants and equipment. He may supervise the drilling, blasting, excavating, and transporting of ores. He must see that the ventilation and water drainage of mine systems function properly. An expert mining engineer is rare; his services are greatly in demand and command high pay.

Photography. That part of photography which deals with the developing and printing of pictures is essentially chemical in nature. In the small privately owned photographic studio, the owner may take the pictures and do his own developing and printing. In the larger establishments developers, or darkroom men, and printers are employed.

Training in this type of work may be secured by serving as an apprentice or by attending a training school. There are many such schools throughout the country, but extreme care should be exercised in the choice of one, as the sole purpose of many is to make money, the training of students being merely window dressing. A list of recommended schools of photography may be secured by writing the Office of Education, the Department of the Interior, Washington, D.C.

Darkroom men earn from $15 to $20 a week. Experts may earn as much as $50 a week. The average day is eight hours, though, in rush seasons, an employee may be required to work overtime. The work is rather confining and is often done in small unventilated quarters. Many darkroom men eventually start small photographic establishments of their own or become skilled in better-paying jobs, such as printing and retouching.

Much of the work is done while standing. Since the hands are constantly in contact with chemicals, people with sensitive skins will be unsuited for this work. A great deal of the work is done under a small red light and is exacting on the eyes. Work may be found in commercial photographic establishments, with large newspaper or magazine publishers, or with many industrial firms.

Ewing Galloway

This man is working in a commercial photographer's darkroom. He is developing negatives and making prints

Other positions offered in the field of photography include those of finishers, retouchers, and cameramen for both still and motion pictures.

Medicine. The profession of medicine is included because, as you have seen, the human body is essentially a chemical organism. A good doctor knows the chemical reactions that take place in the body and the factors that influence these body functions. He must know the effect of medicines upon the body. He must know the nature of anesthetics and how to administer them. He knows the value of antiseptics and when to use them.

A medical career offers unexcelled opportunities for the service of humanity. The desire to be of service to mankind should be the chief aim of those entering this profession. The medical profession offers to an ambitious, industrious, and capable young man or woman a life rich in opportunities for service and growth and, at the same time, provides a comfortable material reward.

The qualifications that a person should have if he is to enter this profession are high. The standards set by the medical profession are difficult to achieve. In the first place, the profession is crowded, so that only those best fitted can expect to qualify. Those students who, in high school, do not rank in the upper 10 per cent or 15 per cent of their class in scholarship will find it difficult to do the strenuous work required of medical students.

A doctor is on call every hour of the day and is often compelled to work in unfavorable circumstances. Only those who have a strong physique and steady nerves should enter this profession.

If you are really interested in becoming a doctor, it is advisable that you have a serious talk with some good physician. Study both the advantages and the disadvantages thoroughly before reaching a decision.

In high school the student should take biology, chemistry, and, if possible, physics. He should also take Latin, algebra, plane geometry, and psychology if offered. He should read as many books and articles in magazines as possible on health, medicine, and science.

In college he is usually required to take a three-year premedical course. He then must take a four-year course in a medical school, followed by one or more years as an intern in a hospital. If he expects to become a specialist, he must take one or more years of postgraduate work.

It is estimated that the average income of doctors is $5000. It usually takes five years or more for a doctor to establish a practice. During this time he may consider himself fortunate if he makes expenses.

The cost of a medical education is high. It is estimated that it costs about $1000 a year to receive such training. The course is so strenuous as to make it inadvisable to work for part of one's expenses.

Many young doctors, upon the completion of their training, flock to the large cities to establish a practice. This has caused serious overcrowding of the profession in urban centers. There is, however, a great demand for good doctors in small rural

Doctors in training benefit greatly from the experience of successful practicing physicians. This group is diagnosing the ailment of a patient from X-ray pictures

Ewing Galloway

Ewing Galloway

Chemistry has played an important role in the training of this dentist and also in that of his assistant. How is their work related to chemistry?

communities. Medical services in these communities are totally inadequate, and the opportunity for service is great.

Considering the cost in time, money, and energy of preparing for the medical profession, one must say that the return in money is not large, but the return in opportunities for service to one's fellow men is great.

Dentistry. The dentist of today is respected for his contribution to the health and happiness of his fellow men. The standards of this profession have been raised to a high plane through the enactment of strict state licensing laws, higher college requirements, and more exacting demands of the public.

There are only about thirty-five recognized dental colleges in the United States. All these require high-school graduation and usually two years of general college work for admission. The usual course is four years, though some colleges have five-year and six-year courses.

Seven branches of dentistry are offered the student. These are (1) *orthodontia*, the straightening of malformed teeth; (2) *exodontia*, tooth extraction; (3) *oral surgery*, the treatment of diseases of the mouth and teeth; (4) *periodontia*, pyorrhea treatment; (5) *pedodontia*, the care and treatment of children's teeth; (6) *prosthodontia*, the making and fitting of substitutes for extracted or other missing teeth; (7) *radiodontia*, X-ray work.

The young dentist must pass exacting state examinations after graduation from a recognized dental college. If successful, he may start a practice of his own, or he may work as an assistant for an older established dentist. Many industrial firms, public-school systems, hospitals, and clinics employ dentists.

The work is interesting, though rather confining. The ideal dentist has a pleasing personality, an abundance of patience, mechanical ability, and the scientific attitude.

The profession of dentistry is less crowded than that of medicine. Fewer dentists are entering this profession than are leaving or retiring from it. The average income of the dentist is about the same as that of the physician, although the top income is lower. It is estimated that the average income of the dentist after ten years of practice is $4300.

Pharmacy. This field of science includes (1) the art of preparing from vegetables, herbs, and animal and mineral substances the drugs and medicines used by mankind; (2) the dispensing of drugs and medicines according to doctors' prescriptions; (3) the compounding of preparations according to formulas.

Pharmacy is recognized as a public-health profession, and its practice is regulated by law in every state. Before receiving a license and before being allowed to practice as a pharmacist, the applicant must pass an examination prepared by some agency, such as a state board of pharmacy. Most states require that applicants be graduates of recognized colleges of pharmacy. Such colleges are often operated by state universities and require four years of training. Students who are interested in this work should write to their state department of health for information regarding the requirements for entering this profession.

About 90 per cent of the graduates of colleges of pharmacy are employed in pharmacies and drugstores. Some of these become owners or managers, and others serve as prescriptionists. Other graduates secure employment with hospitals, manufacturing plants, and industrial laboratories. Some manufacturing plants employ graduate pharmacists as salesmen and representatives. The Federal government employs a number of pharmacists in the army, navy, Public Health Service, Bureau of Narcotics, the Food and Drug Administration, and other divisions. There are about 100,000 registered pharmacists in the United States. Approximately 4000 of these are women.

The salary of pharmacists varies in different sections of the country. The average salary of a new graduate in pharmacy is $30 a week. A few experienced pharmacists earn as much as $60 or $70 a week.

A person entering this profession should possess these traits of personality and character: accuracy, honesty, dependability, and cleanliness. He should also have scientific ability. The work is tedious and exacting. The pharmacist must never make a mistake, as life itself may depend on the correct filling of a doctor's prescription. The work is confining but is interesting to those who like technical scientific work.

Veterinary medicine. The veterinarian does the same things for animals that a physician does for human beings. He helps to prevent diseases of animals. He also helps to cure and eradicate disease. He knows the physiology of animal bodies, can diagnose their illnesses, understands the chemistry of medicines and their reaction on the animal body, and must have the skill of a surgeon.

The veterinarian, like the physician, is on call every hour of the day. He may have to go long distances in bad weather at any hour of the night to treat an animal.

A pharmacist is a chemist who prepares and dispenses medicines. He must be very accurate in his work

Ewing Galloway

Ewing Galloway

The veterinarian must have a scientific knowledge of animals and of their diseases and how to treat them

There are ten colleges in the United States which offer training in veterinary medicine. In all except one, a high-school education plus one year of college is required for admission. The degree D.V.M. (Doctor of Veterinary Medicine) is offered to those who successfully complete the four years of college work prescribed for the degree. In almost all states an examination must be passed before the prospective veterinarian is licensed to practice.

There are a number of different fields for veterinary practice. One may establish oneself in a rural region either as an assistant to a veterinarian, by opening a new office, or by buying a practice already established. A city practice is generally confined to the treatment of cats and dogs. The government employs veterinarians for meat inspection, disease eradication, rodent and insect control, and many other purposes. Likewise, states and municipalities generally employ veterinarians.

In 1930 there was a shortage of veterinarians. Since that time, the enrollment in this course in college has greatly increased to the point where there is grave danger of an oversupply. The American Veterinary Medical Association can provide information about the opportunities in this vocation.

The annual salary may vary from $1000 to $1500 for a veterinary assistant. The average for all veterinarians is over $4000.

Dietitian. Dietetics is the application of the science of food nutrition to the feeding of individuals. Most of the graduate dietitians secure work in hospitals and such institutions as orphanages, schools, universities, and homes for the aged. However, an increasing number are being employed by large hotels and restaurants.

The dietitian in a hospital has many responsibilities. She has general supervision of the preparation of food for the patients and sees that it is served in an attractive manner. She visits patients for food suggestions and is often consulted by physicians who ask her advice about special diets for patients. She studies the diet charts left by physicians and sees that their orders are carried out. She is charged with the responsibility of ordering the food supplies of the hospital. She must be a good manager as well as a scientist. It is her responsibility to give instruction in dietetics to the student nurses in training at the hospital.

The training necessary to become a dietitian requires four years. It is usually given in universities

The dietitian is a food chemist

Underwood-Stratton

which have medical and nurses' training schools in connection with near-by hospitals. In some institutions high-school graduates are allowed to enter special training for dietitians on a basis similar to that of student nurses.

The work of the dietitian is interesting. This profession is held in high esteem because of the high type of service that dietitians render to mankind. It is scientific in nature, since the chemical composition of the food nutrients must be known. The dietitian is a specialist in food chemistry, especially that involving vitamins, minerals, and other nutrients.

The average beginning salary in hospitals or hotels for an assistant dietitian is about $100 a month and maintenance, which includes board and room. As she demonstrates her ability, her salary is increased accordingly. Head dietitians of large hospitals earn from $200 to $300 a month and maintenance.

Cosmetology, or beauty culture. The number of workers in this field has increased tremendously in the last twenty-five years. In the United States there are approximately 200,000 men and women engaged as hairdressers, manicurists, and general beauty operators. The number of beauty parlors also has increased. This increase would indicate that more and more people have formed regular habits of visiting beauty parlors.

The work of a beautician consists in doing everything that is needed in caring for the hair, face, and hands. An operator must know how to meet and talk pleasantly with people. Moreover, she must know the chemical nature of the various cosmetics which are used. A good beauty operator has a bit of the artist's creativeness in his or her nature and is thus able to diagnose individual cases and treat them differently. A clean, wholesome daintiness is expected of a cosmetician.

The wages of a competent operator vary from $15 to $20 a week. Some shop-owners pay their employees on a commission basis. Some allow tipping and percentages on the sale of beauty aids.

The amount of training required varies from six months to two years, and in most states an applicant must be from sixteen to eighteen years old.

You should consult your state board of cosmetology for standards, qualifications, and conditions of work before beginning to study for the vocation, since they vary. Many states require an examination before an applicant is allowed to practice.

Ewing Galloway

Beauty operators must be artistic and skillful; they should also understand the chemistry of cosmetics

There are several related occupations, such as manufacturing cosmetics, demonstrating their use and sale, operating health salons, chiropody (the care of the feet), advertising, and publicity work.

Dry-cleaning and dyeing. There are many different jobs in the dry-cleaning and dyeing industry. The most important work in dry-cleaning is done by the spotter and the dry cleaner, and in dyeing by the dyer. Each of these jobs requires a knowledge of chemistry.

The spotter must be able to identify fabrics; he must be able to determine the source of the stain or spot; and he must know what chemicals to use to remove the stain or spot. This occupation is a highly technical one because there are over a thousand different kinds of stains.

The dry cleaner receives the garments from the spotter and places them in a washer which contains a petroleum base solvent. The garments are washed until clean. The dry cleaner not only must know about solvents but must be able to understand and service the mechanical equipment.

Ewing Galloway

A spotter at work in a dry-cleaning establishment. What knowledge of chemistry should he have?

The dyer must be a highly skilled person. He must know fabrics; he must know dyes and understand the chemistry of dyes; and he must be a master of the processes of dyeing.

Special training for these vocations may be obtained through apprenticeship or by attending a special training school. A high-school education which includes a study of chemistry and physics is recommended. A spotter or dyer can become a master of his trade after about four years of apprenticeship.

Working hours range from forty to forty-eight hours a week. Spotters may receive from $30 to $45 a week; dyers, from $35 to $60; and dry cleaners, from $25 to $40.

Nursing. This profession offers a real challenge to young people who wish to follow a career which is filled with opportunities for being of service to mankind. Nursing deals not only with those who are ill but with thousands who are well, for safeguarding health and happiness is an important part of nursing. Since the nurse must work closely with all kinds of people under all sorts of conditions, she must be sympathetic, patient, and understanding and must have excellent health. She must be resourceful and energetic, and, above all, she must be a scientist. Upon her judgment often depends the life of a patient. So important is this field of work that every state has set up high standards of achievement which must be met before a nurse is allowed to practice her profession.

All good nursing schools require high-school graduation as a prerequisite for entrance, and many require one or more years of college. Any student contemplating this profession as a career should write to The National League of Nursing Education, 50 West 50th Street, New York City, for information regarding the selection of a school of nursing. Additional information regarding the requirements in any particular state may be secured by writing to the state nurses association or the department of health of the state in which you live.

The period of training usually covers three years and includes study and classwork, as well as nursing practice in a hospital. Almost all schools of nursing require the payment of some tuition, and often there is a charge for board and room during the first year in the school. After graduation from the school the student must pass state board examinations before being allowed the privilege of using the letters "R.N." (Registered Nurse) after her name.

The service of the nurse is indispensable to the doctor

Ewing Galloway

Nurses are employed by hospitals, clinics, industrial plants, state departments of health as visiting nurses, and by many public schools and colleges. Many nurses secure employment in private homes, caring for the sick. For those young men who might be interested, this field of work offers many opportunities. Few men enter this profession, but those in it can always find employment.

The salaries received vary greatly with the type of work done and the region in which one lives. Ordinarily the salary range is from $1000 to $1800 a year. Where executive responsibilities are assumed, the salary may be as high as $2500.

EXERCISES

1. Make a classified list of all the vocations which are related to chemistry.

2. What characteristics should a high-school graduate possess who is contemplating chemical engineering as a career? medicine as a career? dietetics as a career?

3. Select the vocation which appeals most to you and write down all the characteristics pertaining to it. Include such things as preliminary training, apprenticeship, chances of securing appointment, and salary that may be expected.

4. Make a short survey of the various jobs which former graduates of your high school have accepted. Consult your high-school principal or your superintendent to learn what percentage of graduates go to college; what percentage graduate from college; what percentage go into jobs which require no previous training.

5. Describe the work of a chemist.

PROBLEMS FOR FURTHER STUDY

1. What other vocations related to chemistry should be added to those discussed in this unit?

2. Make a vocational plan for yourself by following the suggestions given in Problem 1.

3. How does the entrance of the United States into war affect the demand for workers prepared in the vocations described in this unit?

4. How should one go about applying for a job?

REFERENCES FOR FURTHER READING

Clyne, R. W. *Engineering Opportunities.* D. Appleton-Century Company, Inc., New York, 1939.

Covington, Ethel. *The Efficient Dental Assistant.* The C. V. Mosby Company, St. Louis, 1940.

Klinefelter, Lee M. *Medical Occupations Available to Boys When They Grow Up.* E. P. Dutton & Company, New York, 1939.

Klinefelter, Lee M. *Medical Occupations for Girls.* E. P. Dutton & Company, New York, 1939.

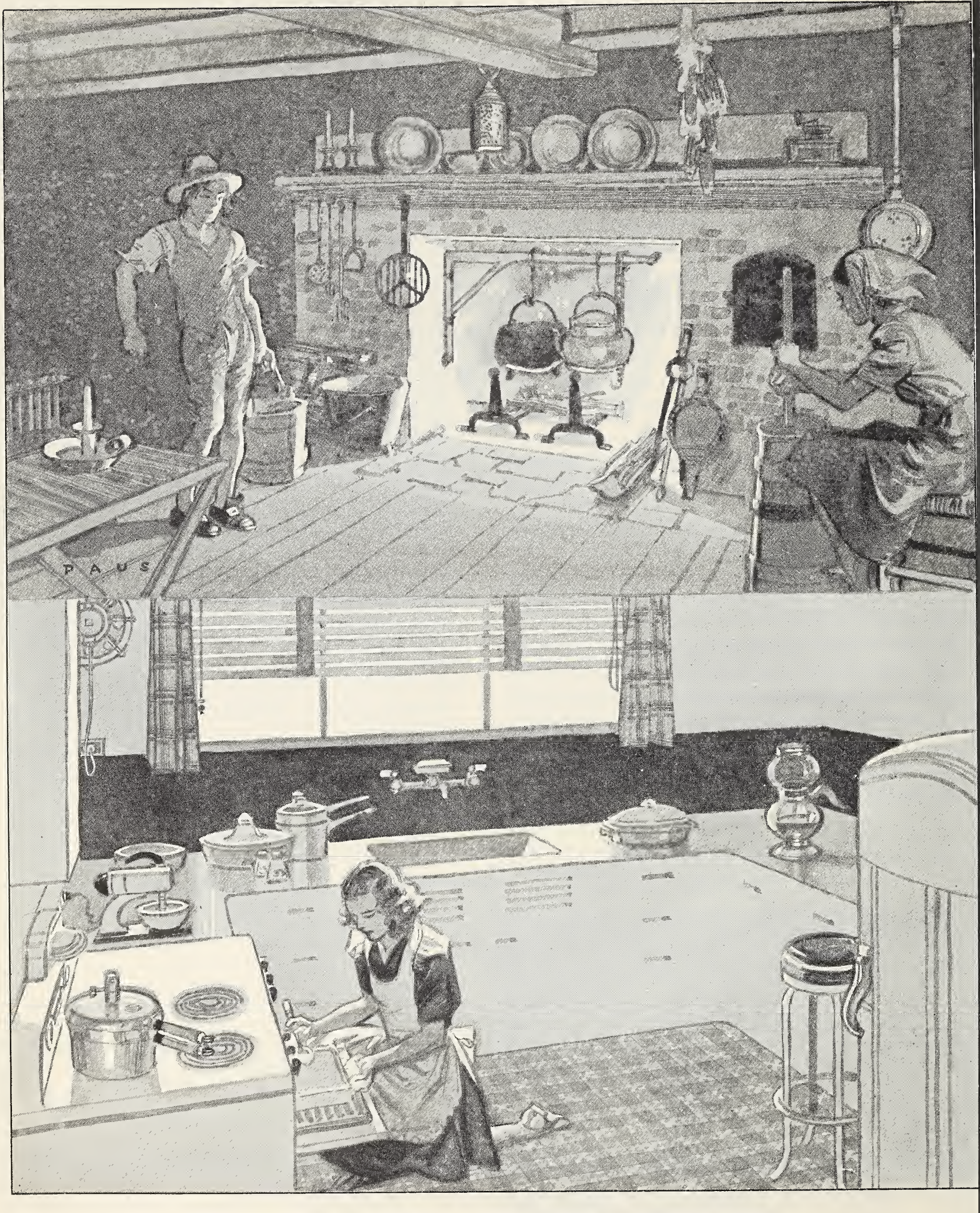
Lingenfelter, Mary, and Kitson, Harry. *Vocations for Girls.* Harcourt, Brace and Company, New York, 1939.

Lufburrow, N. A. *Vocational Interest Locator Test.* Publications Press, 1511 Guilford Avenue, Baltimore, Maryland, 1938.

Woodhouse, C. G. *Dental Careers.* Funk & Wagnalls Company, New York, 1939.

Career Pamphlets, published by The Chicago Institute for Research, Chicago. Bulletins on almost every vocation are available.

Success Vocational Information Series. Morgan-Dillon & Co., 5154 North Clark Street, Chicago. A wide variety of pamphlets on many different vocations.



What has chemistry done to make possible the modern kitchen?

PART III

CHEMISTRY OF THE HOME

UNIT 20

The Chemistry of the Cooking and Preservation of Food

In the earliest times man ate his food in the raw state. Today everyone, high and low, eats food that has been cooked. Just how or when people first cooked food is not known.

Cooking was probably discovered by accident when some primitive man accidentally dropped a piece of raw meat in a campfire. Or possibly an animal, burned in a forest fire, may have been tasted by an early wanderer, and thus the discovery was made. The roasting of game over a fire and the parching of seeds were probably the first kind of cooking. Such cooking required no utensils, and it could be done quickly wherever a wandering tribe of people happened to camp.

Cooking today is a highly specialized art, comprising many procedures which the well-informed housewife or the chef can use to gratify hungry appetites. Today one may bake, boil, broil, stew, fry, steam, or roast food, but he should know the results of each kind of cooking if the food is to be healthfully served. We must not forget that foods are chemical substances, and that heat in any form hastens the speed with which chemical reactions occur. Some of the effects of cooking are chemical changes, and some are merely physical, and the well-informed person understands what they are.

PURPOSES TO BE ACHIEVED

1. To understand the reasons for cooking foods.
2. To understand what part chemistry plays in the cooking of foods.
3. To improve cooking techniques through the use of chemical knowledge.
4. To learn how to cook foods so that the food values are not destroyed.
5. To determine the relative values of home-canned and commercially canned food.

PROBLEMS TO BE SOLVED

1. Why do we cook food?
2. How are foods affected by the different methods of cooking?
    a. What chemical changes take place when food is cooked?
    b. What are the advantages of the various ways of cooking food?
    c. What precautions should we observe in cooking food so that the nutritive values are retained?
3. What makes jellies jell?
4. How are leavening agents used in baking?
5. How is food preserved?

Problem 1. Why do we cook food?

The cooking of food is beneficial to health. The fact that all civilized people now cook most of their food before eating it clearly indicates that there must be good reasons for this practice. There are at least five reasons for the cooking of food. (1) Cooking destroys harmful germs in food and thus prevents the spread of disease. (2) The flavor is enhanced and improved. (3) Food is made more palatable by being improved in appearance. (4) The digestibility of many foods is improved by cooking. (5) Cooking provides a wider variety of foods.

Cooking destroys germs. Harmful microorganisms may be present in foodstuffs when they are first obtained, or they may develop as a result of exposure to contamination through handling. Prolonged heat will destroy these germs. In fact, the cook may be regarded as a sanitary officer, always guarding our health.

It is probably not safe to eat any kind of uncooked meat because of the possible presence of harmful germs. Fresh pork[1] is commonly infested with a wormlike parasite known as trichina. If such pork is eaten without first being thoroughly cooked, one may be infected with this parasite and contract the disease trichinosis. The parasite travels through the intestinal wall into the muscles, where it continues to thrive to the painful discomfort of the "host." Physicians have been unable to find a

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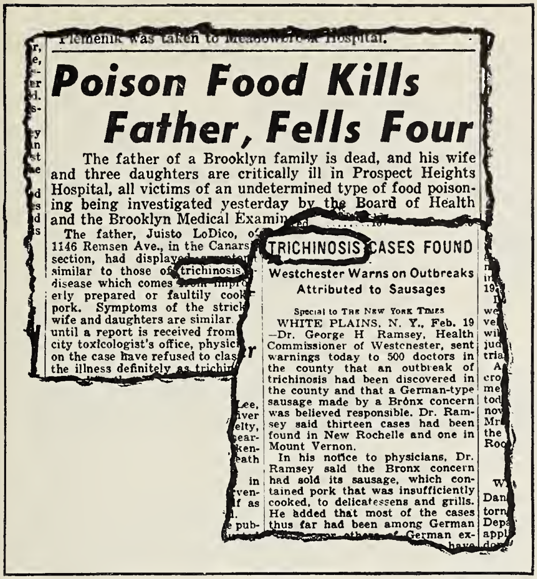
[1] David O. Woodbury, "Never Eat 'Pink Pork,'" *Hygeia*, February, 1938.



Poison Food Kills Father, Fells Four

The father of a Brooklyn family is dead, and his wife and three daughters are critically ill in Prospect Heights Hospital, all victims of an undetermined type of food poisoning being investigated yesterday by the Board of Health and the Brooklyn Medical Examin

The father, Juisto LoDico, o
1146 Remsen Ave., in the Canars
section, had display
similar to those of trichinosis,
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on the case have refused to clas
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TRICHINOSIS CASES FOUND

Westchester Warns on Outbreaks Attributed to Sausages

Special to THE NEW YORK TIMES

WHITE PLAINS, N. Y., Feb. 19—Dr. George H Ramsey, Health Commissioner of Westchester, sent warnings today to 500 doctors in the county that an outbreak of trichinosis had been discovered in the county and that a German-type sausage made by a Brônx concern was believed responsible. Dr. Ramsey said thirteen cases had been found in New Rochelle and one in Mount Vernon.

In his notice to physicians, Dr. Ramsey said the Bronx concern had sold its sausage, which contained pork that was insufficiently cooked, to delicatessens and grills. He added that most of the cases thus far had been among German

Consumers Union

Once in a while stories about trichinosis get into the newspapers. In most communities, however, it is still not a reportable disease. As shown here, doctors often have difficulty in differentiating its symptoms from those of other diseases

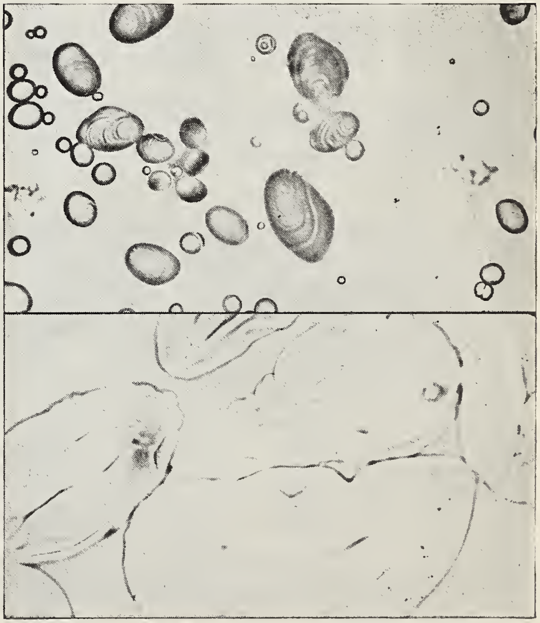
drug or combination of drugs which will cure trichinosis, but persons afflicted with the disease generally recover after a period of weeks or months, provided the attack is not too severe. It is said that 12 per cent of the people in the United States have at some time contracted this disease. One should be particularly careful about Hamburger, which frequently contains fresh pork. If Hamburger is served when it is rare, or pink, it is not safe to eat.

Some garden foodstuffs are grown on land that is irrigated with water contaminated with sewage. Such water generally carries dysentery, typhoid, and tuberculosis germs. It is not uncommon for these germs to lodge on the leafy part of the vegetable and remain there to be eaten later. Of course thorough cooking will destroy such germs, and then the food is safe to eat.

The savory kitchen. Many foods in the raw state, especially meats, are decidedly unattractive in appearance and odor; but when cooked and served hot, they are very appetizing. The delightful aroma that comes from the kitchen or the table just before the family sits down to a meal is due to chemical changes that have been produced in the foods by cooking. The heat supplied by the cooking process produces some of the flavors, and others are caused by the volitalization of substances within the foods themselves.

Cooking improves digestibility. The heat and moisture supplied by cooking make some foods more digestible. For example, foods which contain starch, such as beans and potatoes, when subjected to the temperature of boiling water, are made more digestible because the starch globules are broken. At still higher temperatures the starch is converted into a more soluble substance known as dextrin. Moreover, tough and fibrous foods, such as meats, celery, and parsnips, are softened by cooking, and chemical changes occur which also cause them to be more digestible. Moreover, because pleasant tastes and odors are produced by cooking, the appetite is stimulated and the digestive organs are excited

Two microphotographs, showing starch globules before and after heating [1]



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[1] Reproduced from Cockefair and Cockefair's *Health and Achievement*, Ginn and Company.

to pour forth their digestive juices, so that indirectly more nearly complete digestion is promoted.

Cooking provides a wider variety of foods. The American way of living demands a varied diet, and the cooking of food aids in providing it. Some good foods, such as beans, peas, and corn, would not be included in our diet unless they were cooked. Other foods, such as meats, may be cooked in so many different ways that considerable variety is possible. Thus eating is made more pleasurable through the variety of foods made possible by cooking.

The overcooking of food. Though the cooking of food is necessary to our health and happiness, it must not be assumed that cooking is necessary for all foods. We must eat some foods in the raw state in order to get all the vitamins which we need. Such foods as milk and certain fruits and vegetables may be eaten without cooking. However, they have already been subjected to processes which take the place of cooking; that is, they have been brought to a state of digestibility which is not improved by cooking.

Just as much harm can come from overcooking food as from undercooking it. Overcooking frequently destroys food nutrients, especially vitamins, and makes the food less digestible and less palatable. Therefore it is advisable for everyone to know how much to cook food.

This woman has overcooked cabbage by cooking it for thirty minutes. In this length of time all the vitamins which are soluble in water are dissolved out

E. R. Squibb and Sons

EXERCISES

1. List five reasons for cooking food. Justify each reason you name.
2. What foods are most likely to be overcooked?
3. What foods are best for our health when they are eaten in the uncooked state? Why?
4. What foods should be thoroughly cooked? Why?

Problem 2. How are foods affected by the different methods of cooking?

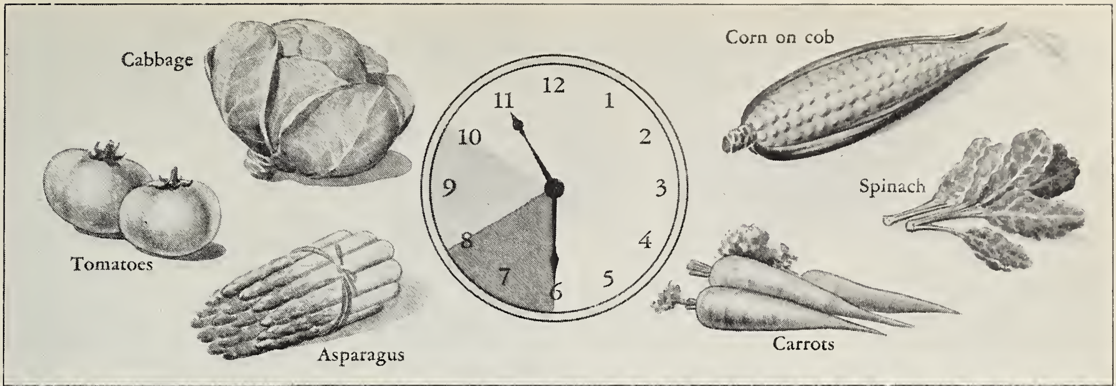
The cooking of vegetables. Most vegetables may be eaten in either the raw or the cooked state, but we have become habituated to the taste of cooked vegetables, and therefore most people serve them in this form. It must be said, however, that it is becoming fashionable to eat more raw vegetables, and this is probably fortunate because in most cases raw vegetables are more nutritious than cooked vegetables. The main thing to guard against is contamination from dirt and germs. Therefore, if vegetables are served raw, they must be thoroughly cleaned. As we shall see, the cooking of vegetables tends to remove or destroy valuable food nutrients; so one rule to remember is that vegetables should not be overcooked.

We prefer the taste of cooked vegetables because they are softer in texture, and in some cases they have a better flavor, even though there is sometimes less nutritive value. The speed of digestibility of some vegetables is increased by cooking, and, in the case of vegetables containing starch, such as potatoes, digestibility is greatly increased.

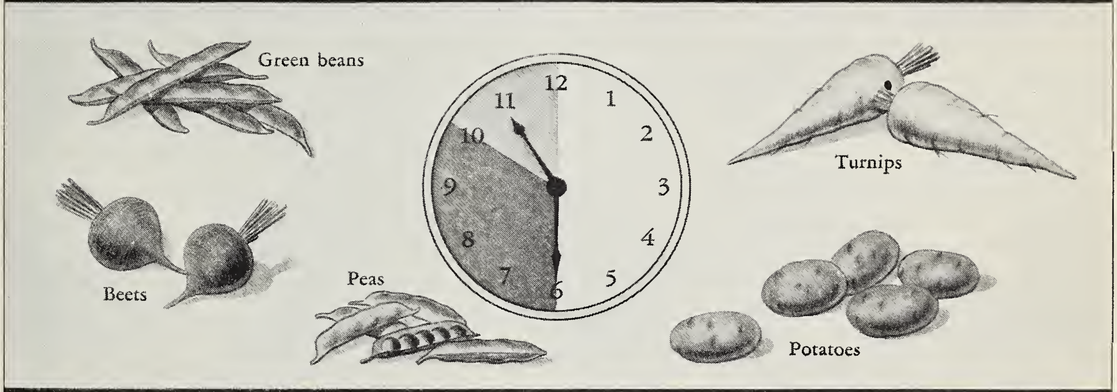
Vegetables contain carbohydrates, proteins, vitamins, cellulose, minerals, and varying small amounts of fat. What happens to these various food nutrients when the vegetables which contain them are cooked?

So far as is possible, vegetables should be cooked so that their nutritive value and palatability are preserved. The texture should not be mushy or soft, but instead should be firm. The original color should be maintained if possible. Overcooking is detrimental to the color, flavor, texture, and nutritive value of vegetables.

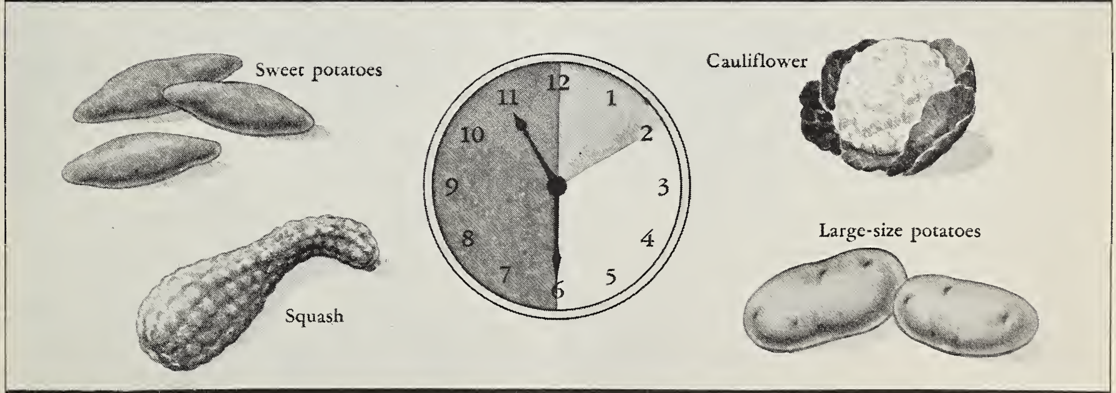
Carbohydrates in vegetables. This food nutrient occurs in vegetables, usually in the form of starch $(C_6H_{10}O_5)_x$ and small amounts of glucose, or dextrose ($C_6H_{12}O_6$). Cooking swells the starch granules,



Cooking time for these vegetables is from 10 to 20 minutes



Cooking time for these vegetables is from 20 to 30 minutes



Cooking time for these vegetables is from 30 to 40 minutes causing them to burst, and thus, when eaten, they are more easily digested. If cooked in boiling water for a long time, there may be a slight hydrolysis of the starch, which changes it into glucose.

There is very little loss of starches and sugars in food, regardless of the method of cooking that is employed, provided that the water in which it is cooked is served with the food.

Proteins in vegetables. The proteins in vegetables are very important to some people, especially vegetarians, and so we should know of any changes that occur in the protein of vegetables when they are cooked. You have already learned that protein compounds differ widely in properties. Because of this fact, they are affected differently by heating. Some of the proteins are soluble in water and therefore dissolve in the water in which the vegetables are cooked. Some proteins are coagulated by heat, either in the cells of the vegetable or in the water in which they are dissolved. This principle of the coagulation of proteins by heat is important to remember, for most kinds of proteins are affected in this manner. The cooking of proteins is complicated because they are generally mixed with other food nutrients that require different treatment to make them ready for digestion. For example, the vegetable foods which contain protein, such as wheat flour, corn, beans, and peas, also contain a large proportion of starch. And we have learned that starches are made soluble by cooking, and thus are more easily digested. Then how are such vegetable foods to be cooked? The guiding principle should be that vegetables containing both these nutrients should not be boiled long. Also, it is best to cook them in water that is relatively soft, because hard water contains calcium and magnesium salts which unite with the protein called legumin to form insoluble compounds that are very difficult to digest. If these principles are adhered to, and the water in which the vegetable is cooked is served with the vegetable, very little protein material will be lost through the process of cooking.

Vitamins in vegetables. Vegetables should be eaten because of the vitamins, minerals, and roughage which they contain. We have learned that these are all very important to our health. Of these three constituents of food, vitamins are by far the most affected by cooking. Vegetables are our principal source of vitamins, and we should be particularly careful in cooking them so that as little as possible of their vitamin content is lost.

Vitamin A is probably less affected by cooking than any of the other vitamins, and its loss through cooking is insignificant. It is a fat-soluble vitamin; and since most vegetables are cooked in water, and since the cooking temperature of vegetables does not decompose it, we do not have to be especially careful in cooking vegetables which contain this vitamin. Carrots, cabbage, and tomatoes are good sources of vitamin A.

Vitamin B_1 is soluble in water, but boiling water does not destroy it. Therefore this important vitamin will not be lost unless the cooking water is thrown away. Vegetables, such as cabbage, lettuce, corn, and carrots, and cereals, such as rice and wheat products, should, therefore, be cooked in as little water as possible, and every bit of that water should be served with the food.

Vitamin C is the vitamin most generally present in vegetables, and is also the most easily destroyed because it is easily oxidized. Since oxidation is increased by raising the temperature and by prolonged heating, it is evident that the cooking of vegetables will destroy this important vitamin. Scientific observers have shown that as much as 95 per cent of the vitamin-C content of vegetables is lost as a result of normal cooking. If the cooking water is slightly alkaline, or if soda is added to prevent loss of color, all the vitamin C will be lost. It has been shown that food substances which contain acids, such as tomatoes and pineapples, do not suffer any significant loss of vitamin C when they are cooked. Vegetables should be cooked at as low a temperature as possible, in covered utensils and in nonalkaline water, if this important vitamin is to be preserved. However, we should remember that a principal source of vitamin C is fresh fruits.

Vitamin D is fat-soluble and is not found in many vegetables. Instead we find it in eggs, liver, and milk. Therefore we need not be concerned about the loss of this vitamin in the cooking of vegetables.

Vitamin E is not destroyed by cooking, and is so universally distributed in vegetables and cereals that we rarely suffer from a deficiency of it.

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How vitamins get lost: (1) Exposure to air (vitamin A). (2) Poured away with water from vegetables (B). (3) Destroyed by heating (C). (4) Fruit juices exposed to air overnight (C). (5) Addition of baking soda to preserve the color of peas (B and C). (6) Stripping the leaves off lettuce and other leafy vegetables. (7) Storage of food

Vitamin G is water-soluble, and vegetables containing it should be cooked in the same way as those containing vitamin B.

Minerals in vegetables. The valuable minerals in vegetables occur mostly as soluble inorganic salts, and the mineral content of the diet may be seriously reduced if the juices of vegetables are repeatedly drained away. Since vegetables are our principal source of minerals, we should make every effort to conserve the minerals in the cooking processes. The longer the vegetables are held in the water, and the greater the amount of water, the greater will be the leaching of the mineral content. Steamed vegetables or those cooked by the "waterless" method lose less of their mineral content than those cooked in the usual way. Regardless of the method employed, all the vegetable juices should be served with the vegetable or utilized in some manner in other foods. One chemical principle that you have already learned—namely, that finely divided particles dissolve more rapidly—should be remembered in connection with vegetable cooking. For example, carrots, when cooked, will retain more minerals if they are whole than if they are diced. In addition, nature has provided a protective peel for vegetables which will help to retain the mineral content if it is not removed before cooking.

The roughage in vegetables. The cellulose in the husks, stems, and leaves of vegetables is not affected by cooking; and regardless of what method is employed, it is not destroyed. The cook should not remove any more of the skins than is necessary when she is preparing vegetables for cooking.

Rules for cooking vegetables. The chemistry of cooking vegetables can be summarized as follows:

1. Cook them in as little water as possible.
2. Serve the cooking water with them.
3. Remember that mineral content and vitamins C, B, and G are most easily destroyed or lost by cooking.
4. To preserve palatability, flavor, and texture undercook them rather than overcook them.

The cooking of animal products. Proteins. We have already learned that we must depend upon meat and other animal products for some of the protein which our bodies need. The foods which contain most protein come from animals. Therefore, in meat cookery, we should be most concerned with the changes that take place in the protein which meats contain. In the laboratory you will perform experiments with protein materials to discover their properties and the effect of heat upon them. You will discover that the white of an egg (which contains 12 per cent protein) will dissolve in water readily, but when this same egg white is first heated to the boiling point of water, it will not readily dissolve. We must remember that the purpose of digestion is to make foods soluble. But the cooking of egg white tends to make it less easily digested. In the cooking of all protein-containing foods, the same principle holds, namely, that heating to too great a degree coagulates the protein, and makes it less soluble and consequently less easily digested. If we adhere to this principle in cooking milk, meats, eggs, and vegetables which contain proteins, these foods will then be most nutritious.

To understand meat cookery, it is well to know the make-up of meat. When meat tissue is examined, it is found to contain muscle fibers, which are rodlike in structure and held together by connective tissue. Fat tissue may or may not be held within the connective fibers. The connective tissue (or tendons) of meat serves the same purpose for muscle fibers as cellulose does for plants; that is, it is the supporting tissue and therefore is a part of all meat. Connective tissue and muscle fibers are both proteins, but are different kinds of proteins and respond differently to heat. Connective tissue contains a protein-like substance called collagen, which is swelled by heating and is thus made more soluble and consequently more digestible. Dilute acids affect collagen similarly, and this accounts for the fact that tough meat can be made more tender by adding a small amount of vinegar. The muscle tissue contains solutions of salts, vitamins in small quantities, and several proteins, such as globulin, albumin, and, in the red meats, hemoglobin. High heat tends to coagulate these proteins, making them less soluble and less digestible. It is obvious, then, that meat should be cooked at a moderate temperature so that these proteins will not be coagulated. If meat contains much tough connective tissue, or collagen, it should first be pounded or soaked in vinegar before cooking is attempted. Freshly killed meat is, as a rule, more tough than meat that has been killed a few days previous to use. The organic acids and enzymes in meat tend to soften the connective tissue after the meat has been killed a few days.

Other nutrients in animal foods. In addition to proteins in animal foods, there are also fats, vitamins, minerals, and some carbohydrates. We need not be much concerned with the loss of these nutrients from cooked animal foods. The vitamins, minerals, and carbohydrates are found in rather small quantities in meat, and the fat undergoes but little change in cooking.

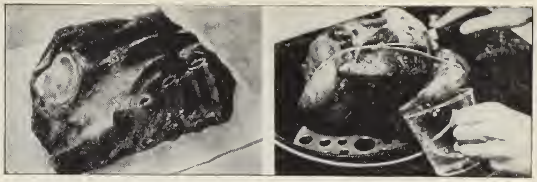
The temperature of most cooking is above that of the melting point of fat, and therefore the fat that is held by the muscle and connective tissue comes out of the meat in liquid form. This liquid fat does not differ in composition from raw fat, but it is more palatable because it has absorbed flavors from the meat.

When fat is cooked repeatedly at a high temperature, some of the low-melting-point fats are volatilized and lost. This leaves a higher-melting-point fat which is harder to digest. For example, it is not uncommon for potato chips, doughnuts, and French fried potatoes to be fried in deep fat which is used over and over again. Such a method may result in economy but will produce a less easily digested food.

The cooking of meat. Basically, there are only two methods of cooking meat, namely, that of moist heat and that of dry heat. Tender cuts may be cooked by dry heat because they contain very little collagen, or connective tissue. The less tender cuts, however, contain more connective tissue, which is softened by water; therefore they should be cooked in moist heat. The common kinds of cooking which are generally considered applications of dry heat are roasting, broiling, and pan-broiling. Examples of cooking by the moist method are braising, stewing, frying, boiling, and simmering.

In the use of dry heat, it was formerly considered necessary to sear the outside surface first in order to seal in the soluble proteins, juices, and vitamins. Recent experiments indicate that this is not necessary, and that cooking at a moderate temperature throughout the process is a better method.

When meat is cooked by moist heat, the soluble substances in the meat, such as minerals, vitamins, and soluble proteins, are extracted from the meat into the water. The longer the cooking process lasts, the greater the amount of extraction. If beef is cut into small pieces and put on the stove in cold water and boiled for two hours, the meat will be tasteless, but the broth will be highly flavored and nutritious. On the other hand, if the meat is plunged into boiling water and then the cooking continued, the flavor of the meat will be preserved because the albumin on the outside will be coagulated, thereby sealing the juices within the fibers. This sealing requires about ten minutes, and then the meat should be cooked until tender at a lower temperature—about 180° F. The stock, or water solution in which the meat is cooked, makes excellent soup or gravy because much of the nutrient and flavoring material is found in it.



For a pot roast, select beef chuck, rump, or round

Add a little water, about one-half cup

Use a pot with close-fitting lid and a rack

Cover and cook slowly until tender all through

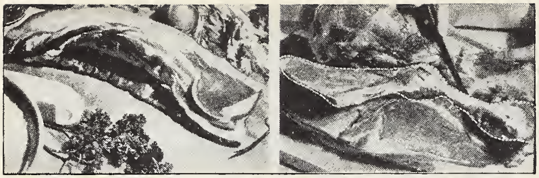
Brown in beef fat to give rich flavor

Add vegetables during the last hour

United States Department of Agriculture

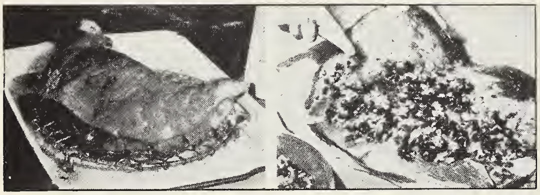
Long, slow cooking with a lid to hold in the steam is the way to make tough meat tender

Chemistry aids in preparing meats for cooking. In recent years, research workers in meat-packing plants have discovered ways of making meats more tender by the use of certain substances which do



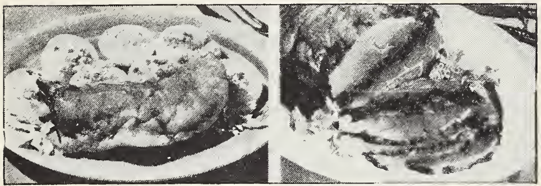
Lamb breast and the materials for forcemeat stuffing

Bone the shoulder; then soak overnight



Open pan with rack and no water

Fill with raisin stuffing and bake slowly (275° to 300° F)



United States Department of Agriculture

Stuffed lamb breast with onions

A boned roast is easy to carve

For good stuffed roasts try lamb shoulder, fresh ham, pork shoulder, and spareribs

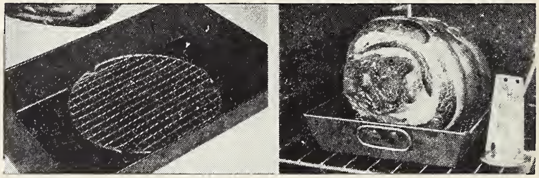
not impair the nutritional or health qualities of the meat. This process is known as tenderizing. The exact formulas of the substances used are protected by patents, but the general process may be told. In producing tenderized hams, potassium nitrate, potassium nitrite, and sodium chloride solutions are injected into the hams by forcing them under pressure into the main artery which enters the ham. In this way, the solutions penetrate every fiber of the ham via the subdividing arteries and capillaries. The collagen and other albuminoids in the connective tissue are broken down by the nitrites, and thus the ham need not be subjected to so much heat to make it tender. The Federal government inspectors protect the consumer in specifying the concentration of nitrites and nitrates to be used. Most states do not have as stringent requirements for meat as the Federal government, and therefore it is probably safer to buy meat which is processed for interstate commerce.

The cooking of eggs. The albumin of an egg starts to coagulate at a temperature of 135° F, which indicates to us how an egg should be cooked. The best method is to place the egg in boiling water and, without further heating, allow it to stand for from five to ten minutes. The overcooking of eggs hardens the albumin of both the white and the yolk, which makes the albumin difficult to digest. A hard-boiled egg will require twice as long a time for digestion in the stomach as a properly cooked soft-boiled egg because it takes that much longer for a hard-boiled egg to get into solution.

Boiling and frying. When food is placed in boiling water, we must remember that the food cooks at the boiling temperature of the water. As long as the water continues to boil, the temperature remains constant, and it is useless to try to get the food to cook faster by making the water boil faster. Since the boiling point of water varies with alti-

The easy, modern way to cook any tender roast of beef, lamb, or pork, with a good covering of fat

United States Department of Agriculture



Open pan with rack and no water

Brown lightly in a hot oven (450° to 500° F); then lower the heat and finish slowly

Placed fat side up, a roast is self-basting

Or roast at moderate heat (about 350° F) for the entire time

A thermometer to tell when the roast is done

Plump, brown, juicy, evenly cooked

tude, foods will cook much less quickly on the top of Pikes Peak than in New York City. In Denver the boiling point of water is 95° C, whereas in New York it is 100° C. The reason for this lies in the fact that an increase in pressure causes an increase in the boiling point. An appliance used in the home which makes use of this principle is the pressure cooker. In this appliance the steam is held within, causing an increase in pressure, which, in turn, causes the boiling point of the water to rise above 100° C. For every 10 degrees rise in temperature, the speed of a chemical reaction is doubled; consequently the food placed in a pressure cooker will cook more rapidly.

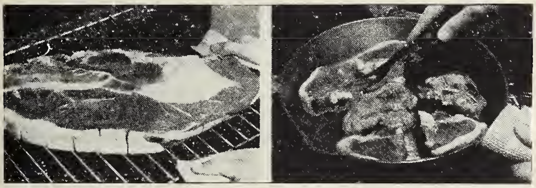
To fry food is to cook by both moist and dry heat. Temperatures higher than boiling water are acting on the food, and therefore frying is similar to broiling and baking. However, since the food is bathed in a liquid (fat), it is being cooked by moist heat. The frying of food is generally looked upon with disfavor because the food may be partially charred and also because it is likely to become soaked with fat. The burning of food makes it indigestible, and the accumulation of fat around the proteins and carbohydrates interferes with their digestion in the stomach. However, frying in deep fat, as is usual with doughnuts, is permissible. Soggy fried foods should not be eaten, but properly fried foods eaten in moderation may constitute a part of the diet.

Whether broiling with direct heat or pan-broiling, sear quickly and then finish at moderate heat

United States Department of Agriculture

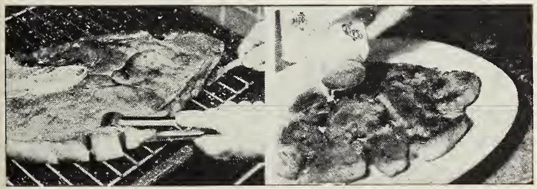
For broiling, select tender cuts with plenty of fat

For pan-broiling use a hot skillet



Start a steak or chops in a hot broiler

No water and no lid, because steam draws the juices out of meat



Brown quickly on both sides; then finish slowly

Season steak or chops after broiling

Pound in flour and seasoning

Spread with stuffing and roll from the side

Brown in beef fat to give rich flavor

After browning, cover, and finish in a moderate oven (350° F)

United States Department of Agriculture

Add tomatoes or water, cover, and finish slowly

Stuffed flank steak with potatoes

A less tender cut may be used in such braised dishes as casserole and brown stew

EXERCISES

1. What food nutrients are found in vegetables?
2. How should vegetables be cooked to preserve the nutrients and yet be palatable?
3. What nutrients are most likely to be lost when vegetables are cooked? Why?
4. What difficulties are likely to be encountered in cooking vegetables which contain considerable protein?

5. Make a list of the vitamins found in foods. Describe each one from three points of view: its properties, its sources, and the readiness with which it is lost in cooking.

6. What precautions should be observed in the cooking of vegetables to preserve their mineral content? Explain the "waterless" method of cooking vegetables.

7. Why should we include meat in our diet?

8. What substances are found in lean meat?

9. When meat is cooked, what happens to the fat which it contains?

10. How should tough meat be prepared for cooking? Why?

11. List the various ways of cooking meat and describe the effect of each method on the meat.

12. Is it harmful to eat fried meat? Why or why not?

Problem 3. What makes jellies jell?

The chemistry of jelly-making. It is customary to make jelly by boiling fruit juice with sugar. The boiling is continued until the right concentration of the solution is reached. When this solution is allowed to cool, a jellied product is obtained. This product is primarily due to a polysaccharide called pectin. When pectin is concentrated in the presence of sugar, the resultant product is a *colloidal* solution, which, when cooled, forms a jellied structure.

In order that you may gain a conception of a colloidal solution, it will first be necessary for you to recall what a true solution is and the cause of the formation of a precipitate in a solution. From your study of solutions you will remember that in a true solution the dissolved particles are so finely divided that they are actually scattered as molecules. The reason for the precipitation of a dissolved substance is that the molecules of the substance band together into such large particles that they cannot remain in solution. The size of the particles that make a colloidal solution is between that of the particles of a true solution and that of the particles of a precipitate. Colloidal solutions cannot be filtered, and many times they exhibit a jelly-like consistency.

As fruit grows, a chemical called protopectin is produced. When the fruit begins to ripen, the protopectin is changed to pectin. When the fruit becomes ripe, the pectin is changed to pectic acid. Pectin is the only chemical which, when concentrated with fruit juice and sugar, will produce a colloidal solution and result in jelly. It is for this reason that housewives fail in an attempt to make jelly from the juice of overripe fruit. Success in jelly-making will be much more likely if slightly underripe fruit is used.

Another method of making jelly seems to be displacing the one referred to above. It is now possible to buy commercial pectin, which is a product extracted from apples and citrus fruits. When this pectin is mixed with fruit juice and sugar and the resulting solution is boiled for a short time, a superior type of jelly is produced. Such jelly is considered superior to that produced by the prolonged boiling of fruit juice and sugar because of the retention of the fruit flavors. Another advantage of using commercial pectin is that less sugar is required. Experiments tend to show that this type of jelly can be made more economically than the other type.

Gelatin (animal jelly), which is obtained from the bones of animals, has the same property as pectin. When gelatin is dissolved with sugar in hot water, a colloidal solution forms. This colloidal solution produces jelly on cooling. When gelatin is mixed with sugar and fruit flavoring a very palatable food is obtained. Such a mixture is sold under several well-known trade names.

EXERCISES

1. Define a colloidal solution. What is the difference between a true solution and a colloidal solution?

2. Explain the formation of jelly when fruit juices are cooked with sugar.

3. What is pectin? How is it produced in fruits?

4. What is the difference between commercial gelatins and jelly?

Problem 4. How are leavening agents used in baking?

Why do we use leavening agents? There are three reasons why leavening agents are used in making bread and cake. First, bread or cake made with a leavening agent is light and therefore easily chewed. Second, since foods baked with leavening agents are full of holes, the digestive juices come in contact with the food more readily and digestion is greatly facilitated. Third, bread or cake made with such agents is much more palatable and appetizing. If we like the flavor, we naturally eat more and receive more nourishment.

Any process by which dough is filled with holes which are retained upon baking may be used to leaven bread. It is known that ancient peoples mixed flour with water or milk and let it ferment until bubbles of carbon dioxide appeared. This fermented dough was kneaded and baked. Care had to be used not to allow excess fermentation, or putrefaction, to occur. These people later discovered that if some of the fermented dough was kept, whether dry or moist, and added to new dough, fermentation took place more rapidly. Though they did not know it, they were making yeast, or "light," bread. Wild yeast plants in the air caused the fermentation, producing the carbon dioxide gas which caused the bubbles.

Kinds of leavening agents. The leavening of bread may be done by three general methods. Aerating the dough, or whipping air directly into it, has been used to a small extent. The flavor resulting from this method is not very desirable and has limited its general use. Yeast is widely used commercially, and to some extent in homes. Bread bought at a grocery store is made in this way, as are most of our pan rolls and some sweet breads. The third method of producing leavening action is the use of chemicals. There are three general kinds of these: (1) baking soda, (2) baking powder, and (3) ammonium carbonate. The first two find wide use in home baking, but the third is very limited in its use. Ammonium carbonate is principally used in the commercial manufacture of crackers.

Yeast as a leavening agent. Yeast is a microscopic plant, no species being large enough to be seen with the naked eye. Countless millions of these small plants are pressed together to make the common yeast cake. If a bit of yeast cake is mixed with a little water and examined under a microscope, small bodies similar to those shown on this page may be seen. Under proper conditions, these little plants increase in number very rapidly. It is in the process of growth that the gas carbon dioxide is formed. Yeast plants all require sugar for food, moisture, and a warm, even temperature to bring about reproduction and growth. Bread dough is a good medium for this growth, since it contains some sugar which has been mixed with the flour. Some of the starch of the flour is also converted into sugar by the action of enzymes, or organic catalysts. When the sugar is acted upon by the yeast, the two products alcohol and carbon dioxide gas are formed, as shown by the following equation:

The formation of a group of yeast cells. Reproduction is by budding[1]

$$C_{12}H_{22}O_{11} + H_2O + \text{yeast} \longrightarrow 4\ C_2H_5OH + 4\ CO_2$$

As the gas is formed, the small bubbles are trapped in the dough, causing the increase in volume. Baking causes the dough to solidify around the bubbles, thus producing light bread. The heat drives off the alcohol.

Bread factories cultivate special varieties of yeast plants. Different varieties of yeast impart slightly different flavors to bread. Yeast cakes, either dry or moist, are purchased by the housewife for making rolls and breads. Yeast breads, when well cooked, are very palatable and have a flavor which is enjoyed by most people.

Baking soda as a leavening agent. Baking soda, or sodium bicarbonate, has the formula $NaHCO_3$ and is sold by grocers as bicarbonate of soda. Baking soda will liberate carbon dioxide when heated and when treated with an acid. When heated, the products are carbon dioxide, water, and sodium carbonate, or washing soda:

$$2\ NaHCO_3 + \text{heat} \longrightarrow Na_2CO_3 + H_2O + CO_2$$

Soda biscuits are made by thoroughly mixing baking soda with flour and then mixing with shortening and sour milk. When the biscuits are placed in the oven, the heat causes the lactic acid of the milk to react with the baking soda to produce carbon dioxide. The liberation of this gas causes the biscuits to be leavened, or raised. The equation for this reaction is as follows:

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[1] Reproduced from H. J. Conn's *Bacteria, Yeast, and Molds in the Home*, Ginn and Company.

$$\overset{\text{Baking soda}}{NaHCO_3} \overset{+}{+} \overset{\text{lactic acid}}{CH_3CHOHCOOH} \longrightarrow \overset{\text{sodium lactate}}{CH_3CHOHCOONa} + \overset{\text{water}}{H_2O} + \overset{\text{carbon dioxide}}{CO_2}$$

The residue, sodium lactate, is a harmless material and has no effect on the biscuit. Precaution must be used to see that the proper proportion of soda and of sour milk is used. If an excess of soda is used, sodium carbonate, or washing soda, is formed. This will react with the lard or fat which is used as shortening to form soap, causing an unpleasant taste and a brown color.

When baking soda is used to make a cake, the recipe sometimes calls for cream of tartar or lemon juice as the acid ingredient.

Baking powder, a ready-mixed leavening agent. The difficulty of getting the correct amounts of baking soda and sour milk, and the fact that sour milk was not always available, caused chemists to seek a more reliable method of producing leavening in bread by chemical means. Baking powders were first put on the market about 1850, and have largely displaced the baking-soda method of making bread.

All baking powders contain three ingredients: (1) baking soda, which produces the carbon dioxide; (2) a dry acid-forming substance, or acid salt, which forms an acid by hydrolysis; and (3) starch, which helps to keep the mixture dry so that the other two ingredients will not react with each other.

Since several acid salts are available, there are several different types of baking powders on the market. They are usually classed as (1) the alum baking powders, (2) the phosphate baking powders, and (3) the cream of tartar, or tartrate, baking powders. Each type contains baking soda and starch. Some contain a small percentage of dried egg white, or albumin, which helps to form a tough film around the bubbles of gas. Some contain more than one of the acid salts, making a double-acting type of powder, which will be explained later.

1. *Alum baking powders.* This type of baking powder contains sodium aluminum sulfate ($NaAl(SO_4)_2$) as the acid ingredient. This salt hydrolyzes in water to form sulfuric acid, as follows:

$$2\ NaAl(SO_4)_2 + 6\ HOH \longrightarrow Na_2SO_4 + 2\ Al(OH)_3\downarrow + 3\ H_2SO_4$$

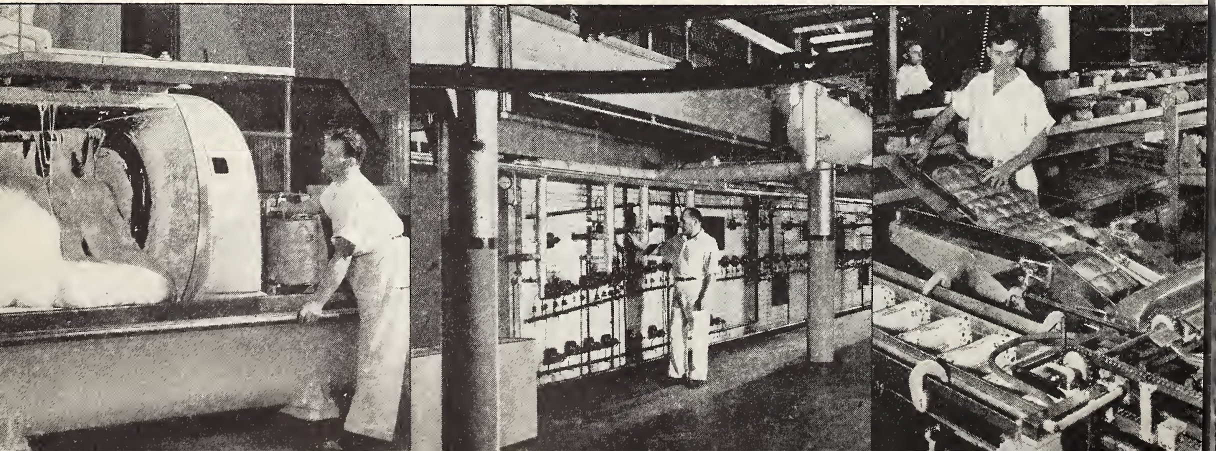
The sulfuric acid reacts with the sodium bicarbonate to form carbon dioxide, which produces the leavening action:

$$6\ NaHCO_3 + 3\ H_2SO_4 \longrightarrow 3\ Na_2SO_4 + 6\ H_2O + 6\ CO_2\uparrow$$

Both the equations given above may be expressed as one equation as follows:

$$NaAl(SO_4)_2 + 3\ NaHCO_3 + 6\ HOH \longrightarrow 2\ Na_2SO_4 + 6\ HOH + Al(OH)_3\downarrow + 3\ CO_2\uparrow$$

Powders containing sodium aluminum sulfate are often designated as S.A.S. powders. This type of powder reacts slowly at room temperature. For



This necessary food is made light in texture because of the yeast plants which are put into the dough before it is baked. The individual yeast cells are constantly subdividing, thus producing countless numbers of other yeast cells. In this living process carbon dioxide is given off, thereby causing the bread to be filled with many tiny holes

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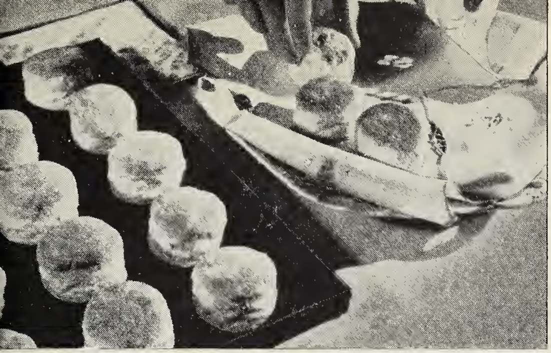

These biscuits are made light by the carbon dioxide released from the leavening agent, sodium bicarbonate ($NaHCO_3$)[1]

this reason, one does not have to be in a hurry to place the dough or batter in the oven; in fact, it is often better to let it stand for a while before baking, to give the reaction time to take place. There is no evidence to show that the aluminum hydroxide or the sodium sulfate is harmful, despite certain opinions expressed by persons interested in other types of baking powders.

2. *Phosphate baking powders.* The acid ingredient of this type of baking powder is soluble calcium acid phosphate, and the equation for its leavening action is as follows:

$$Ca(H_2PO_4)_2 + 2\,NaHCO_3 \longrightarrow CaHPO_4 + Na_2HPO_4 + 2\,H_2O + 2\,CO_2$$

This form of calcium acid phosphate is obtained from bone ash treated with sulfuric acid. The rate of reaction in this type of powder is rapid because of the readily available hydrogen ions in the acid salt. Batters and doughs containing this salt must be baked quickly, since the carbon dioxide is given off soon after the water or milk is added. There is no evidence to show that the presence of the Na_2HPO_4 is harmful.

3. *Tartrate baking powders.* This type of baking powder contains cream of tartar, or potassium acid tartrate ($KHC_4H_4O_6$), as the acid-forming ingredient:

$$KHC_4H_4O_6 + NaHCO_3 \longrightarrow KNaC_4H_4O_6 + H_2O + CO_2\uparrow$$

Potassium acid tartrate, or cream of tartar, was the first substance added to baking soda to make baking powder. It is formed from grapes when the juice is converted into wine, and is rather expensive. Since it is an acid salt, it reacts rapidly, and baking must take place rather soon after mixing. Not enough Rochelle salt ($KNaC_4H_4O_6$) is formed to have any effect on persons eating bread made with cream of tartar baking powder.

Double-acting baking powders. Very often a manufacturer uses both calcium acid phosphate and sodium aluminum sulfate as the acid-forming ingredients in his particular brand of baking powder. The advantage of this kind of baking powder is that the first acid ingredient begins to act very soon after being mixed with the dough or batter, whereas the second reacts more slowly, during the baking. Examine the cans of several brands of baking powder and report upon the composition of each brand.

EXERCISES

1. What is a leavening agent? Describe three different leavening agents.
2. Why is bread which has been made by the use of leavening agents called light bread?
3. How is yeast produced? What is yeast?
4. What are the kinds of baking powder which are commonly sold? What is the composition of each?

This food is made possible because chemists have found that a certain mixture of chemicals, under the influence of heat, will release carbon dioxide and leave no harmful by-products. What products of the reaction are left in the cake?

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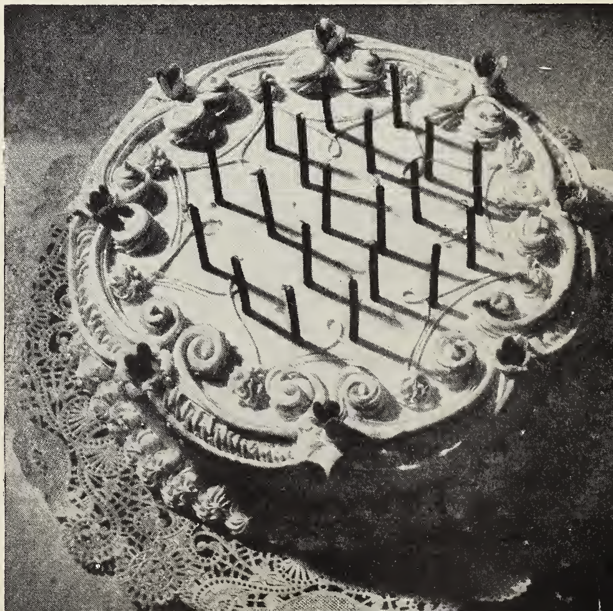

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[1] Reproduced from Stanley and Cline's *Foods, Their Selection and Preparation*, Ginn and Company.

5. Show, by the use of equations, how an alum baking powder liberates carbon dioxide.

6. What are the differences between baking soda and baking powder?

7. What is a double-acting baking powder?

8. Consult your mother about the kind of baking powder that she uses and find out why she prefers that particular kind.

Problem 5. How is food preserved?

Why is it necessary to preserve food? You are probably acquainted with the fact that most food will spoil after it has been exposed to the air for some time. This spoilage is due to the growth of microorganisms in the food. In many cases, the chemical decay produced by these microorganisms is harmless; but in other cases, the decayed food contains dangerous toxins which are very harmful to the body.

The processes used in the preservation of food retard spoilage, and consequently remove a potential danger to the body. This, however, is not the only reason for the preservation of food. Through the process of preservation, it is possible for the foods of all nations and all regions to be made available to everyone, wherever he may live. Fresh fruits and vegetables and other perishable foods can be grown in California, shipped to the markets in New York City, and sold to consumers in a condition comparable to the condition in which they are offered in their local markets. The preservation of food also makes possible more reasonably priced food, particularly during the winter, when large quantities of foods which have been preserved by cold storage or other means can be sold at lower prices than would be possible if the same foods were available in quantities natural to the season. The restriction of the consumption of foods to their growing season has been forever removed by food preservation.

Methods of preserving foods. There are many ways of preserving foods. The discussion in this text will be limited to the most important ways, which are drying, chemical preservation, refrigeration, and heat penetration. You should be familiar with the processes used in each of these methods of food preservation.

Drying. Food preservation by drying has been practiced since ancient times. It was customary to hang food in sheds or place it on screens or boards until it was dry. This practice is still followed, but today the drying of food has become a commercial industry in which controlled conditions make possible mass production.

The preservation of food by drying is based upon the removal of water. When water is removed from food, the possibility of the growth of microorganisms is lessened, because water is necessary for their growth. The amount of water which needs to be evaporated depends on the amount of sugar in the food. The greater the amount of sugar, the less the drying that is necessary. This is due to the fact that a high concentration of sugar will aid in the preservation of food.

In the period immediately preceding 1931, there was little drying of food in the home. During the economic crisis that began to be generally felt at this time, the practice was to a large degree restored. Many families, especially in rural areas, have resorted to dried foods for economical living. Many new processes have been discovered, and food of excellent quality has been preserved by drying. It is, however, generally recognized that dried foods are not as palatable as fresh or canned foods; and there is evidence to prove that dried foods lose some of their vitamin content.

Another method of preserving food is shown here. Why does dried food not spoil?

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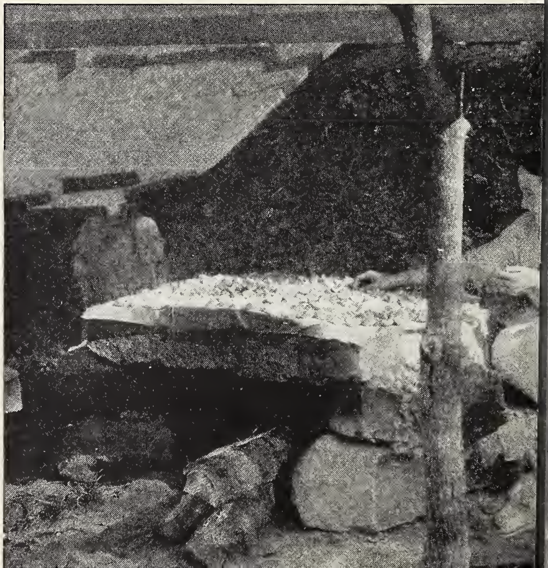

Chemical preservation. Many chemicals have the property of destroying or checking the growth of microorganisms. Some of these chemicals are used in the preservation of foods. Others, if used, would be harmful to the body and are prohibited by the pure-food laws. Some chemical preservatives are harmful unless they are limited to a certain percentage. Thus sodium benzoate may be used to the extent of 0.2 per cent in preserving some foods.

Chemicals are often used to supplement another preservative. For instance, tomato catchup, which has already been spiced and given the heat treatment, often has sodium benzoate added to it for its additional preservative value. Sulfur dioxide (SO_2) is frequently used in fruits which are being preserved by drying. When either of these two chemicals is used, the United States government requires that it be declared on the label of the food if the food is to be shipped in interstate commerce.

Some chemicals are used for purposes other than preservation. Thus sulfur dioxide (SO_2) will prevent the darkening of dried fruits, and sodium sulfite (Na_2SO_3) and potassium nitrite (KNO_2) (frequently referred to as "dynamite") may be added to discolored Hamburger or other meats to restore the fresh, red color.

A harmless food preservative is common table salt. Foods preserved with salt are fully protected against the growth of microorganisms. At least a part of the preservative action of salt is due to a principle known as osmosis. Osmosis takes place when water passes through a cell membrane into a solution of higher concentration. Thus water is removed from the food, so that the food is preserved because it has been partially dried. Many meats are preserved with salt. Eggs are often preserved by packing them in salt or in water glass (Na_2SiO_3). The preservative action of these two chemicals in the case of eggs is due to their ability to keep air and microorganisms from passing through the porous shell and causing putrefaction.

Other substances which are used in food preservation are smoke, spices, and formaldehyde. The preserving action of smoke is due to the presence of organic chemicals called phenols. Fish and meats such as bacon and ham are often smoked to ensure their preservation. Spices contain organic aldehydes which inhibit the growth of germs. Formaldehyde is sometimes used to preserve milk, although many municipalities have laws against its use because it is a strong poison.

The most commonly used chemical preservative is sugar. It is effective against the growth of all microorganisms except molds. Its preservative action is due to its absorption of water from the microorganisms.

Food preservation and health. The preservation of food with certain chemicals, if properly and lawfully practiced, is an aid in providing more wholesome and varied diets. Who would deny that jams and jellies, preserved by the action of sugar, or smoked ham and bacon, preserved by smoke and drying, are valuable additions to our diet? On the other hand, the use of improper and unlawful methods of preservation is a menace to health. The policy of using "dynamite" to make meat appear fresh even when it has begun to putrefy should never be sanctioned by consumers. Some unscrupulous meat vendors sell "dynamited" Hamburger very cheap to attract customers to their stores. Though this practice is unlawful in most states and one which should be reported to health authorities, it is not uncommon.

Let us consider some of the other dangers of the use of chemical preservatives. Fresh, ripe, unblemished tomatoes make excellent catchup when cooked and spiced. They do not require the addition of sodium benzoate. It is only those tomatoes that are not of first quality that require this chemical for the preservation of catchup.

Milk is undoubtedly the most valuable of all foods. It is also one of the foods that are most readily contaminated with germs, especially if it is not properly handled. If it is properly cared for and pasteurized, it requires no added preservative. And yet many unscrupulous dairies, which do not care to go to the expense involved in the proper handling of milk, will compensate for poor sanitation and delay in delivery by using the preservative formaldehyde. Such a practice should be outlawed by discriminating consumers.

Thus the preservation of food by chemicals may be valuable, or it may be very detrimental to health. The improper use of chemical preservatives, with its accompanying dangers, is due to antiquated laws and unintelligent consumers. To change such con-

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How does the refrigeration of foods in transit add to the variety of our daily diet?

ditions will necessitate the education of the consumer, who in turn will demand protective laws.

Refrigeration. Refrigeration is a convenient and widely used method of preserving foods. The preserving action of refrigeration is due to the fact that low temperatures check the growth of microorganisms and, in some cases, destroy them.

It is not the purpose at this time to discuss in detail the types of refrigeration, such as "ice" refrigeration, "iceless" refrigeration, and quick freezing. Such a discussion will be found in Unit 24. However, it is important that you realize the value of refrigeration in the preservation of food, and the advantages of its use.

Any housewife can tell you about the value of refrigeration. She knows that whether food is cooked or uncooked, it can be kept for a much longer period of time in a refrigerator. She probably knows what the principle of refrigeration is, namely, that when food is placed in a storage chamber at a relatively low temperature, the growth of germs is retarded and therefore the food does not spoil as soon as it otherwise would. The convenience of home refrigeration and the saving of food made possible thereby have become very important to the modern household.

The same type of refrigeration, on a larger scale, is used in industry. Meat products and fruits and vegetables are shipped to all parts of the world in refrigerator cars, trucks, and ships. By this method it is possible not only to open new markets for food products produced in many localities, but also to supplement the diet with fresh foods, regardless of the season of the year.

Quick freezing. Some years ago the idea was conceived that meats, fruits, and vegetables could be frozen by the same slow process by which ice is frozen and shipped to any part of the country, and frozen fish, strawberries, peas, etc., were offered for sale. Those who purchased this food discovered that when it was thawed, it became wilted and flabby. This was caused by the fact that in the slow-freezing process, the water in the foods was frozen, forming large crystals which destroyed the cell structure of the food.

In very recent years it has been discovered that when food is frozen quickly at a temperature of – 40° C, the crystals formed are very small and do not pierce or destroy the cell walls of the food. Food frozen by this method can be preserved indefinitely and, when thawed, retains its original freshness. Strawberries preserved in this way are as luscious as when they were first picked.

The quick-freezing method is growing by leaps and bounds. Foods processed in this way are used extensively by hotels and restaurants, and their use in private households is spreading rapidly.

Food preservation by canning—heat penetration. Few people think of Napoleon Bonaparte when they open a can of vegetables. However, the canning of foods, as a method of preservation, was discovered in his time in France. The French government offered a 12,000-franc reward to the person who could devise a method of preserving the harvest of foods from one year to another. This would ensure better food supplies for the armies. After years of experimenting, François Appert found that he could preserve foods if they were heated and placed in clear, hot water. He won the award, and, though he did not know the scientific reason for this method of preservation, a great industry was born.

In most homes, at least one can of preserved food is opened every day. Many an economical housewife puts up many jars or cans of fruits and vegetables in the summer and fall to be used during the long winter months.

The principle involved in canning is that of killing the germs through heat penetration and then sealing the can, thus preventing the entrance of any new germs from the air. Commercially, this is done by placing the food in tin cans, heating for a short time to sterilize the air, sealing, and then processing, or heating, to cook the food. The housewife may use this method, sometimes called the cold-pack or cook-in-can method; but she generally uses the open-kettle method.

The success of home canning depends upon several factors. It is known that acid-containing fruits and vegetables are more easily canned than such vegetables as corn, peas, and beans. The reason for this is that food-spoiling germs do not thrive well in an acid medium. While fruits and vegetables containing acid may be canned by heating to 100° C and sealing, those containing no acid, such as corn, peas, and beans, must be heated to from 115° C to 120° C and also be cooked for a longer period of time. Many housewives have little difficulty in canning tomatoes, but often experience great difficulty with other vegetables. To secure the higher temperatures necessary, it is best to use a pressure cooker, since an increase in pressure increases the temperature within the cooker.

Long cooking tends to destroy the vitamins present, especially vitamin C, and to darken the color of the food, as well as impair the flavor. For this reason, the careful housewife or canner will heat the food only as hot as is necessary and for as short a period of time as is required. Generally speaking, the regulation of time and temperature is more uniformly secured through automatic machinery and commercial methods than is possible by home canning methods.

It is hard to estimate the amount of food canned in the home. However, the canning industry has an annual output of between eight and nine billion cans. One of the reasons why the average life span of man has been greatly increased is that today he is assured of not only an abundance of food through canning, but also a greater variety, which ensures a more healthful diet the year round.

Home-canned versus commercially canned foods. The relative merits of these methods of canning have been argued by many authorities. The arguments can be summed up in the following statements:

American Can Company

The application of chemical knowledge to the canning of foods has made it possible to preserve many foods indefinitely. How does canning preserve foods?

1. Home canning is useful for housewives who have the time, the equipment, and an abundance of fruits and vegetables.
2. Open-kettle canning is apt to destroy vitamin C because the food is exposed to the oxygen of the air. This method is therefore not advised except for foods of a high acid content, such as tomatoes, apricots, and peaches. The acid medium preserves vitamin C in these foods.
3. The higher temperatures and presealed cans employed by commercial canners ensure better canned vegetables than can be obtained by the usual home methods. In the commercial method more heat penetrates the inner portions of the food, and the higher temperature kills heat-resisting germs that might not be destroyed by home canning methods.
4. There is no danger of metallic poisoning from the present-day machine-made, lacquer-lined, machine-sealed cans used by modern commercial canners.
5. Commercially canned food, as well as home-canned food, may be left in an opened can without any more fear of spoilage than if it were immediately emptied into another container. In fact, there is less danger of spoilage because the can is sterile, whereas the other container probably is not.

6. Food canned by either method, if made absolutely sterile and sealed airtight, will be preserved indefinitely.

7. Tin cans should not be jammed and dented. If a can bulges at either end, this indicates that there are gases inside it caused by putrefaction. Such a can should be discarded without being opened.

8. Home-canned vegetables may be a source of the disease known as botulism. This disease is produced by a spore-bearing kind of bacteria which resists heat under 100° C. Commercial canners can their vegetables at temperatures of from 115° C to 121° C and therefore ensure the destruction of these germs.

Poisoning caused by decomposed food is generally misnamed ptomaine poisoning, because the illness caused by eating such food is usually caused by other organisms than those that produce ptomaine substances. The medical profession is discouraging the use of the term *ptomaine*, as it does not accurately describe any disease.

EXERCISES

1. What are the advantages of preserving food?

2. What part does chemistry play in the preservation of food? What chemicals are used?

3. Briefly describe the various methods of food preservation.

4. Explain how hams are tenderized.

5. Consult a meat-packer or butcher in your locality on the subject of the making of wieners, or "hot dogs." Try to determine the origin of the term *hot dog.*

6. What control over food preservation should the government exercise in order to safeguard health?

7. Why does refrigeration preserve food?

8. What difference exists between quick-frozen food and that which is frozen by ordinary methods?

9. What is the history of food preservation by canning?

10. How does canning preserve food?

11. What foods are easily canned? Why?

12. What foods are difficult to can? Why?

13. Which are better, commercially canned foods or home-canned foods? Why?

14. What is ptomaine poisoning? What does your doctor say about it?

PROBLEMS FOR FURTHER STUDY

1. How are foods adulterated?

2. How is dried beef prepared? Is it as nutritious as fresh beef?

3. Write to your state home-economics department or to the Bureau of Home Economics in the Federal Department of Agriculture, and ask for information about the effect of altitude on baking and about the changes necessary in a recipe to be used at a high altitude.

4. Make an investigation of the milk-inspection department of your city or state. Determine how prevalent the use of formaldehyde is as a preservative.

5. Examine the labels on bottles of tomato catchup to see how many brands contain benzoate of soda.

6. Look on the labels of baking-powder cans to see what the ingredients of different brands are.

7. Obtain information about the quick-freezing process of preserving foods, and make a report to the class.

8. Make a survey of the meat markets in your locality to determine how prevalent the practice is of using "dynamite."

9. Write to the bureau of health in your state and ask about the rules and regulations governing the selling of fresh meat.

UNIT EXERCISES

Some of the statements which follow are true, and some are false. On a separate sheet of paper write the word *true* for those which are true and the word *false* for those which are false. Do nothing for those about which you are doubtful. Rewrite the false statements so that they are true.

1. Cooking is a modern art.

2. The cooking of food is an art.

3. The cooking of food destroys the food nutrients.

4. Home canning is superior to commercial canning.

5. Chemical changes occur when food is cooked.

6. All uncooked food is less nutritious than cooked food.

7. The digestibility of food is increased through cooking.

8. Cooking destroys harmful germs in food.

9. Trichina is a parasite which sometimes infests beef.

10. Rare Hamburger is a healthful food.

11. It is impossible to overcook food.

12. The starch in uncooked starchy vegetables, such as potatoes, is easily digested.

13. Pork should be thoroughly cooked before being eaten.

14. Vegetables become harder in texture when cooked.

15. Most vegetables contain all the food nutrients.

16. $(C_6H_{10}O_5)x$ is a carbohydrate.

17. $C_{12}H_{22}O_{11}$ is a hydrocarbon.

18. Starches and sugars in vegetables are easily lost in cooking.

19. All methods of cooking preserve the vitamins in vegetables.

20. Vegetables should be covered with water when they are cooked by boiling.

21. Some vegetables contain proteins.

22. Some proteins are coagulated when heated, whereas others are made soluble by the same treatment.

23. One purpose of the digestion of foods is to change them into soluble form.

24. The white of an uncooked egg is soluble in water.

25. Hard-boiled eggs are more easily digested than soft-boiled eggs.

26. Carrots are a good source of vitamin A.

27. Vitamin B is water-soluble.

28. Vitamin C is easily destroyed by exposure to air.

29. Vitamin C is easily destroyed by cooking in alkaline solutions.

30. Citrus fruits are a poor source of vitamin C.

31. Vitamin D is fat-soluble and is found in milk.

32. Vitamin G is found in vegetables.

33. The "waterless" method of cooking vegetables prevents loss of vitamins.

34. The cooking of vegetables destroys the cellulose which they contain.

35. The connective tissue of meat contains collagen.

36. Collagen is more soluble after heating.

37. Muscle tissue containing globulin is less soluble after being heated.

38. The rapid cooking of meat is a desirable method.

39. Meats contain large amounts of vitamins.

40. Roasting is an example of the moist cooking of meat.

41. The best method of soft-boiling eggs is to boil them gently for three minutes.

42. Jellies are made with the use of propectin.

43. Jellies are good examples of colloidal solutions.

44. Very ripe fruit produces the most pectin.

45. Baking powder and baking soda are the same compounds.

46. All leavening agents produce CO_2.

47. Yeast is one of the oldest leavening agents.

48. A baking powder may be made by mixing the correct amounts of $NaHCO_3$, $Ca(H_2PO_4)$, and $NaAl(SO_4)_2$ together.

49. Yeast converts sugar into alcohol and carbon dioxide.

50. Baking soda and sour milk make a good leavening agent.

51. Phosphate baking powders contain no alum.

52. Potassium acid tartrate is cream of tartar.

53. The carbon dioxide produced by the leavening agent stays in bread while it is being baked.

54. Double-acting baking powders contain two acid-forming compounds.

55. When sodium benzoate is used as a food preservative its presence must be declared on the label.

56. Refrigeration prevents the spoiling of food because germs cannot grow at low temperatures.

57. All milk should be pasteurized.

58. Food canned at the boiling temperature of water and sealed airtight is preserved because all germs are killed.

REFERENCES FOR FURTHER STUDY

Daniel, E. P., and Memsell, H. E. *The Vitamin Content of Foods*, Bulletin No. 275, United States Department of Agriculture, Washington, D.C.

Eddy, W. H., and Dalldorf, G. *The Avitaminoses.* The Williams & Wilkins Company, Baltimore, 1937.

Fishbein, Morris. *Your Diet and Your Health.* McGraw-Hill Book Company, Inc., New York, 1937.

Jordan, E. O. *Food Poisoning and Food-borne Infection.* The University of Chicago Press, Chicago, 1931.

Laughlin, Rosemary. *Conserving Food Value, Flavor and Attractiveness in Cooking Vegetables*, United States Department of Agriculture, Washington, D.C.

McCollum, E. V. *The Newer Knowledge of Nutrition.* The Macmillan Company, New York, 1929.

McLester, W. B. *Nutrition and Diet in Health and Disease.* W. B. Saunders Company, Philadelphia, 1931.

Rose, M. S. *Feeding the Family.* The Macmillan Company, New York, 1929.

Rosenau, M. J. *Preventive Medicine and Hygiene.* D. Appleton-Century Company, Inc., New York, 1935.

Sherman, H. C. *Food and Health.* The Macmillan Company, New York, 1934.

Sherman, H. C. *The Vitamins.* Chemical Catalog Company, Inc., 1931.

Tanner, F. W. *The Microbiology of Foods.* Twin City Printing Company, Champaign, Illinois, 1932.

Williams, Paul M. *Government Grading of Canned Fruits and Vegetables*, United States Department of Agriculture, Washington, D.C.

Chemical Composition of American Food Materials, Bulletin No. 28, United States Department of Agriculture, Washington, D.C.

National Standards for Farm Products, Circular No. 8, United States Department of Agriculture, Washington, D.C.

Notices of Judgment, Food and Drug Administration, United States Department of Agriculture, Washington, D.C.

The Vitamins, American Medical Association, Chicago.

UNIT 21

The Chemistry of Cooking Utensils

Perhaps you had not thought of the kitchen in your home as a modern chemical laboratory, with its foods the raw materials and its cooking utensils the laboratory apparatus. We have already seen how the foods we prepare and eat are really chemicals. The cooking utensils, the pots and pans, are made of chemicals, and the thrifty housewife should select vessels made of the proper materials with which to prepare the daily meals.

Probably more change has been made in the kitchen by scientific discoveries than in all the rest of the house. It has not been many years since the housewife had to prepare her meals on a coal or wood range with a few iron kettles. She had to put her foods in a wooden icebox and draw the water from an iron pump or from a single cold-water faucet. Even so, she considered herself lucky, for her grandparents probably had no stove but had to cook in an open fireplace, had no icebox for keeping the food fresh and wholesome, and probably had to draw the water from a well which was located outside the house.

Today the modern housewife may have an electric or gas range, an electric refrigerator, an array of aluminum or chromium-plated utensils, heat-resisting glassware, and many electric appliances. This modern equipment is largely the product of the research laboratory and is manufactured by chemical processes. The next time you are not too busy with other work, go into your kitchen at home, survey the equipment that you find there and see how many different kinds of materials are used in making that equipment. Copper, glass, clay, aluminum, iron, tin, are the most common materials of which kitchen equipment is made.

The use of these materials and appliances, which have been provided through scientific research, has removed much of the drudgery from the tasks of the housewife. It has made it possible for her to prepare better meals more economically, at a great saving of time.

PURPOSES TO BE ACHIEVED

1. To gain a knowledge of the materials of which cooking utensils are made.
2. To learn how the materials of a cooking utensil affect cooking.
3. To recognize the dangers resulting from the use of different types of cooking-utensil materials.
4. To learn how to buy cooking utensils wisely.

PROBLEM TO BE SOLVED

What are the important facts that you should know about cooking utensils?

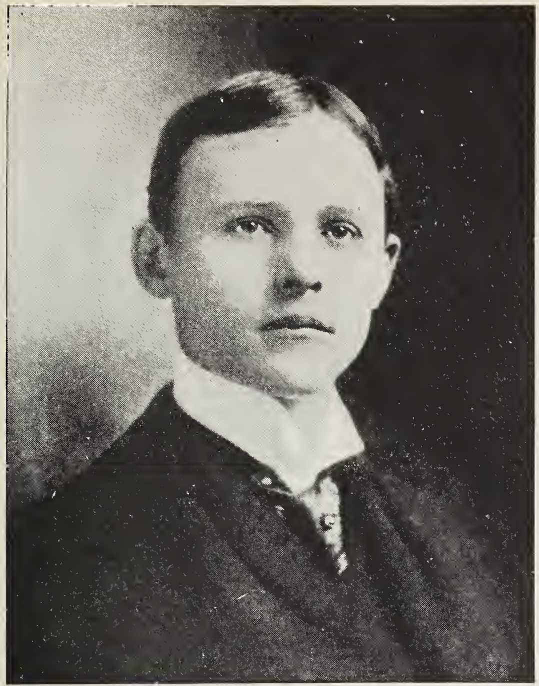
In this unit there will be a discussion of cooking utensils made of aluminum, tin, iron, copper, glass, and clay. The following questions will be considered as each type of utensil is discussed:

1. How is this type of utensil made?
2. What are the advantages and disadvantages of this type?
3. What dangers accompany the use of this type?
4. How should this type of utensil be cared for?
5. What factors should be considered when purchasing utensils of this type?

Problem. What are the important facts that you should know about cooking utensils?

A chemistry student's gift to the world. Perhaps your grandmother can remember the day when she proudly showed the family her first new shiny aluminum pan. Aluminum utensils were rather expensive at first, and very few people had them. Today there is hardly a kitchen without several aluminum pans, and many housewives have a complete set of aluminum ware. As a matter of fact, many women have nothing but aluminum ware in the kitchen when they should have cooking utensils made of various materials.

Charles Martin Hall sat in his chemistry class in Oberlin College in 1886 and listened intently as



Aluminum Company of America

Charles Martin Hall (1863–1914), one of the immortal men of chemistry, discovered an inexpensive commercial method of extracting aluminum from its ores

Professor Jewett told of aluminum and how it was extracted from its compounds by displacement with sodium. The professor told of the unsuccessful attempts that had been made to extract it by electrolysis. He told the class that the person who discovered a cheap method of extracting aluminum not only would become a benefactor of mankind, but would reap a large fortune. Charles Hall decided on that day that he would solve the riddle of aluminum extraction.

Soon after he had graduated from college, he began working in earnest on the problem. Other chemists had unsuccessfully tried to extract aluminum by the electrolysis of a low-melting ore of aluminum, cryolite (Na_3AlF_6), which is obtained from Greenland. This was because the cryolite did not ionize in its molten state. The young chemist Hall began to reason that perhaps the molten cryolite would dissolve some other compound of aluminum, which would dissociate and act as an electrolyte. He built a crude furnace out in the woodshed, melted a quantity of the cryolite, and added a small amount of powdered bauxite, or aluminum oxide (Al_2O_3). The mixture produced a molten mass. Would it act as an electrolyte? He placed the carbons from some old batteries in the molten solution and connected them with an electric current. He allowed the current to flow for a time, and after the mixture had cooled, he found that a few small beads of aluminum were in the mass. His experiment was successful, and a great industry was born. The importance of this industry can be realized from the fact that in a recent year over 300,000,000 pounds of aluminum were produced, to be used in making electric conduit lines, airplane bodies, light alloys, aluminum paint, foil for covering foods, small hardware, cooking utensils, and countless other things.

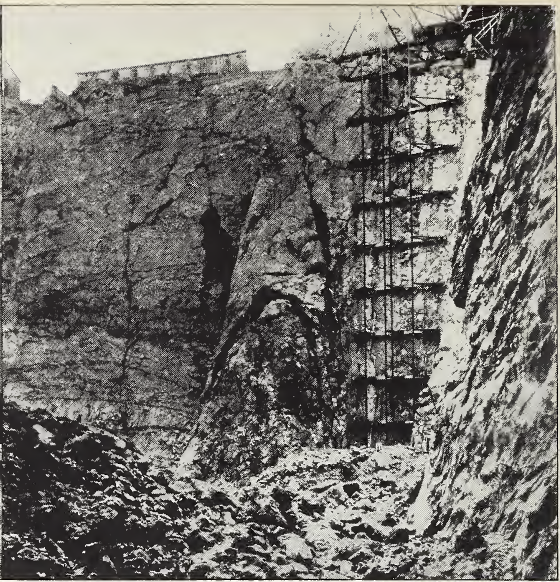
Aluminum is an essential war material. The value of aluminum as a war material, principally in the manufacture of airplanes, was brought forcefully to the attention of all American housewives shortly before the entrance of the United States into the second World War. They were asked to contribute to the government those aluminum utensils

Crown jewels of the aluminum industry. The small globules, on the left, were made by Charles Martin Hall in 1886; the larger one, on the right, is the first commercial aluminum produced by the Hall electrolytic process

Aluminum Company of America

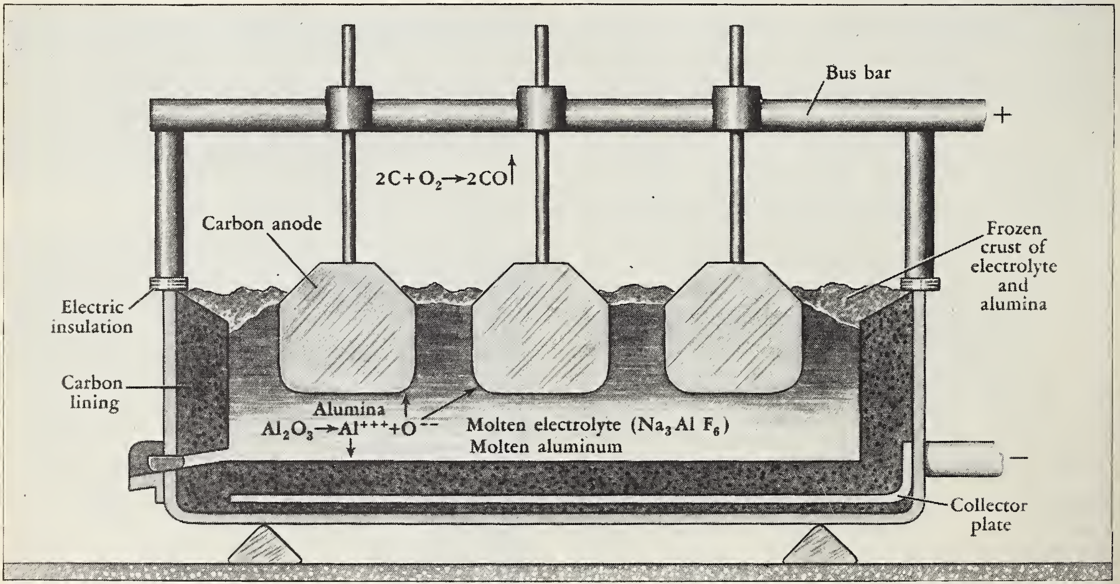
Aluminum Company of America

Mining bauxite, the ore of aluminum, by the open-pit method



Aluminum Company of America

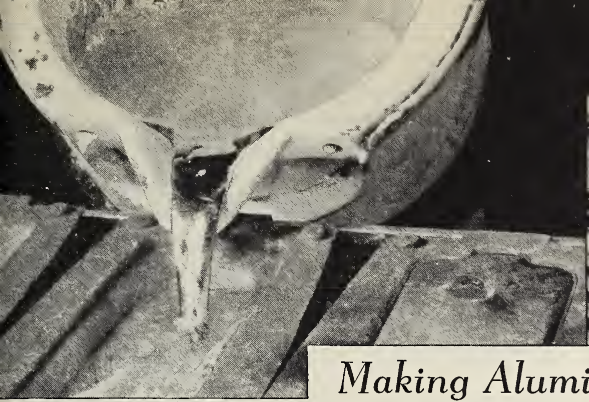
Cryolite, a sodium-aluminum-fluoride mineral, mined in Greenland


Bus bar
+
$2C+O_2 \rightarrow 2CO\uparrow$
Carbon anode
Frozen crust of electrolyte and alumina
Electric insulation
Carbon lining
Alumina
$Al_2O_3 \rightarrow Al^{+++} + O^{--}$
Molten electrolyte (Na_3AlF_6)
Molten aluminum
−
Collector plate

Aluminum Company of America

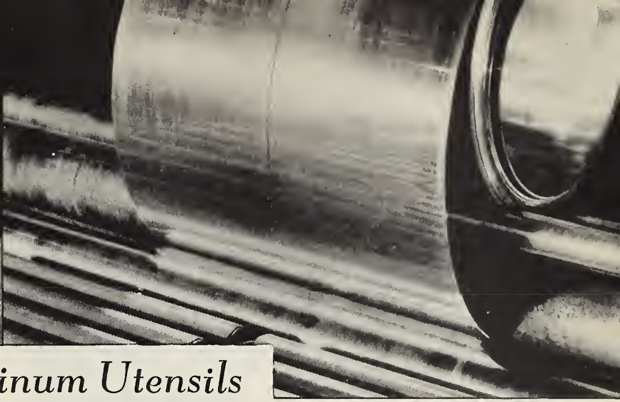
A diagram of the Hall-Héroult electrolytic cell. The electrolyte is molten cryolite, which is the solvent for the alumina, or aluminum oxide (bauxite), and serves as the conductor of the electric current. The intense heat of the electric furnace keeps the electrolyte and the aluminum, which forms on the collector plate, in a molten state. The molten aluminum is drained off at the bottom and cast into ingots

Making Aluminum Utensils



Aluminum Company of America

Molten aluminum is being poured into molds, in which it cools and solidifies to form rectangular bars, or ingots



Aluminum Company of America

Cold-rolled aluminum coming from the mill

Aluminum Company of America

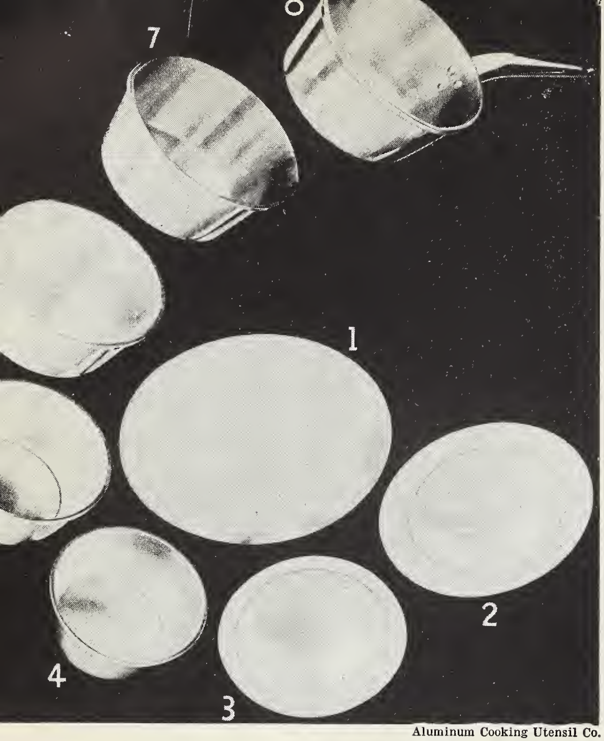
Here the aluminum bars are being rolled into thin plates

Aluminum Company of America

Here the aluminum plate is being cold-rolled to the desired thickness for kitchen utensils. Cold-rolling produces extra hardness and durability

Aluminum Company of America

The sheet aluminum is cut and pressed into desired shapes. Thus utensils can be made without seams. In making a cast-aluminum utensil, the alloy is melted and poured into a mold



Aluminum Cooking Utensil Co.

Eight steps in the manufacture of an aluminum cooking utensil

and other aluminum articles which were not being used. The entire production of new aluminum was diverted from the manufacture of peacetime articles to the manufacture of airplanes and other essential war materials. It became impossible for housewives to buy new aluminum ware after merchant stocks were depleted. Peacetime production in existing aluminum plants was greatly increased, and new plants were constructed. Thus, because of the national emergency, the amount of aluminum produced in the United States has been increased.

The manufacture of aluminum cooking utensils. Sometimes aluminum cooking utensils are cast from the molten metal, especially the heavy utensils, such as pots and skillets. Sheet aluminum is sometimes pounded into shape to form a utensil, since aluminum is very malleable; or aluminum may be spun into the desired shape.

The advantages of aluminum cooking utensils. Aluminum conducts heat very readily, is very low in density, and if polished is bright. Aluminum corrodes rather easily, but the corrosive film acts as a protective coat against further corrosion. The discoloration due to corrosion is not as objectionable as that of iron or copper.

Aluminum utensils may be purchased at rather reasonable prices, though some house-to-house salesmen may convince the unsuspecting housewife that his particular brand is very economical at a high price. Usually such salesmen exaggerate the saving of vitamins and food minerals by the use of their particular brand. In most cases, you can buy utensils of equal quality at a hardware, department, or ten-cent store at a much lower price.

Do aluminum utensils poison foods? This question has often been raised in regard to aluminum cooking utensils. The statement has been made that some of the aluminum dissolves in the cooking food and is a poison to the body. Extensive studies by unbiased scientists have not disclosed this fact. However, there are some foods which should not be cooked in aluminum utensils. Since aluminum is a rather active metal, it is readily acted upon by most acids, and consequently foods such as tomatoes and fruits, which contain acids, should never be cooked in aluminum utensils. To do so may produce an undesired flavor and may cause the utensil to pit more readily. Moreover, aluminum is even acted upon by alkaline foods and bases, which action usually causes discoloration and pitting. Baking soda, washing soda, or lye should never be placed in aluminum utensils.

The care of aluminum utensils. Aluminum pans and kettles may be bought in various weights. Since aluminum is a soft metal, it is very malleable and may be dented easily. Care must be taken with thin aluminum not to dent it. Aluminum is easily scratched and cut, and often a pan is ruined by cutting with a knife. Since aluminum has a low melting point, there is some danger that holes will be burned through the bottom of thin pans if all the water is allowed to evaporate from the cooking foods. All aluminumware has a tendency to pit because of the activity of aluminum. Aluminum sometimes displaces small amounts of other metals in foods, causing an objectionable discoloration of the utensil. There are cleaning materials on the market containing sodium silicate in colloidal form, which will prevent some of the pitting and discoloration. Heavy rolled aluminum or cast aluminum makes the best cooking utensils.

Are aluminum skillets as good as those made of iron? Aluminum is one of the best conductors of heat, whereas iron is a relatively poor conductor. For this reason, iron holds the heat better and produces a more even heat for the substance being cooked. This property seems to produce better fried meats and other foods, and the best chefs prefer a heavy iron utensil for frying.

Utensils made of tin. A tin can contains very little tin. In reality, it is an iron can covered with a very thin coating of tin. The rusty corrosion of an old tin can discloses the presence of iron as the basic material of which the can is made. You should remember that iron is relatively high in the displacement, or activity, series of metals (see page 83) and, as you would expect, corrodes readily. Unless the surface of iron is coated with a protective covering, it will soon rust. Tin is relatively low in the displacement series and consequently is not acted upon chemically by weak or dilute acids, and it has the property of adhering to the clean surface of many other metals.

Iron is plated with tin by first "pickling" a sheet of iron in dilute sulfuric acid. This removes any iron oxide and leaves the surface perfectly clean. The clean sheet iron is then immediately immersed in molten tin. As the sheet iron is withdrawn from the vat, a thin coating of tin adheres to the surface of the iron, thus producing tin plate. This tin-plated iron is the material of which are made the millions of tin cans that are used daily to preserve a large percentage of the food that the nation consumes.

Tin is mined in the faraway Malay States and the Dutch East Indies and in Bolivia, and is rather expensive. None is produced in the United States. A can, cup, or plate made entirely of tin would be expensive.

Tin plate can be pressed, cut, or crimped into various shapes. It finds some use in kitchenware, especially in pie and cake pans. It has the advantage of retaining its shiny luster and is inexpensive. Care should be used to avoid scratching through the tin covering, as the iron will begin to rust as soon as it is exposed to air and moisture.

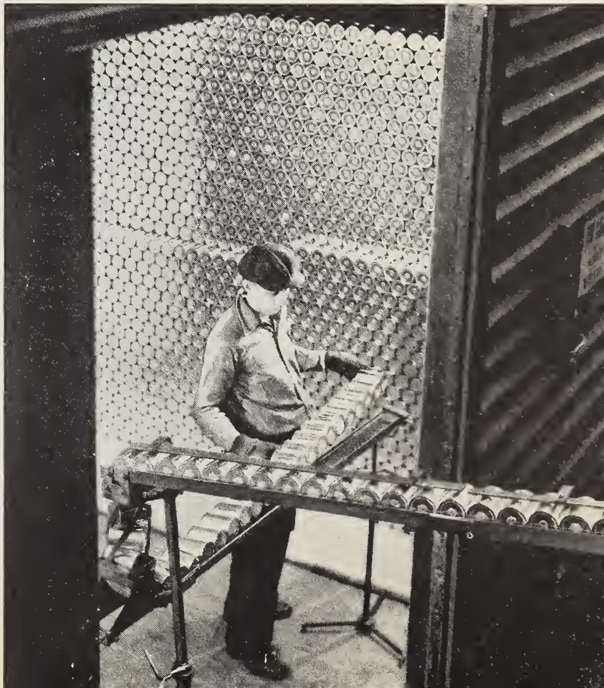
Utensils made of iron. One of the common household articles carried by the early pioneers as they pushed westward to take up homesteads on the virgin land was a big black iron kettle. Larger than a tub, it served many purposes. Each week a fire was built under it in the yard, and the family wash was put to boil. Homemade soap was used to cleanse the clothes—soap which had been made in the same kettle. The lard which was used daily in the kitchen was rendered, or made, in this same kettle. In the pioneer kitchen were to be found many iron utensils, —iron because it is rugged and sturdy,—for the replacement of utensils took a long time and was expensive. Often these iron utensils were handed down from generation to generation.

We still find a number of iron utensils in many kitchens. Most skillets are still made of iron; and though they are not so shiny and beautiful as copper or chromium-plated skillets, they are perhaps the best type of utensil for frying.

Some of these skillets are made of cast iron, and the more expensive may be made of wrought iron or steel. The thinner type of skillet is pressed from sheet iron and is useful for many purposes. For frying and broiling, however, the heavy, thick iron skillet is preferred by many housewives. Iron is a slow conductor of heat, as compared with aluminum and copper, and so retains its heat longer, thus providing a more even cooking temperature.

Tin cans and tin cooking utensils are useful because the tin coating is not attacked by the acids and bases present in foods

American Can Company



National Enameling and Stamping Co.

This iron washtub is being galvanized by being dipped into molten zinc

Even though cooking utensils are washed thoroughly, enough grease usually remains on iron vessels, such as skillets, to provide a thin protective coating which prevents the metal from rusting. Iron utensils are usually cheap and are very useful in the kitchen. Many housewives possess "Dutch ovens," thick iron kettles with heavy lids. They say that they can cook more savory and palatable roasts, Swiss steaks, etc. in these because of the even temperatures maintained and because of the retention of juices, owing to the condensing of the steam generated and held within the vessels.

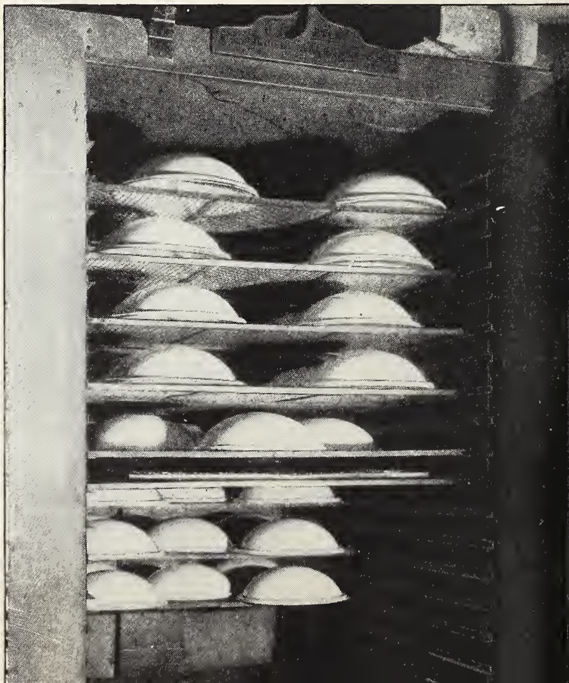
In a later unit (pp. 485–488) you will learn how iron is smelted from its chief ore, hematite (Fe_2O_3), and made into cast iron, wrought iron, or steel.

Galvanized-iron utensils. Many garbage pails, washtubs, and water buckets are made of sheet iron covered with a protective coating of zinc. Iron treated in this way is known as galvanized iron. Iron rusts rapidly if exposed to moisture. For this reason, it cannot be made into containers for garbage or water unless covered by a protective coating. Zinc is relatively high in the activity series and consequently corrodes rapidly. However, the zinc oxide which is produced on the surface soon forms a thin, white, insoluble coating which protects the zinc from further corrosion. Since zinc compounds are slightly poisonous, utensils made of this material cannot be used for cooking purposes.

Enamelware. Enamelware is made by coating an iron or steel utensil with a glassy, or vitreous, material. This material, enamel, is usually baked, or fired, on the metal and is composed of sand, borax, and bone ash (calcium phosphate) or white clay. There should be no lead in it because of the poisonous nature of this metal. However, since the inclusion of lead oxide produces a heavier and harder enamel, it is often present in the enamelware on the market. It probably will have little effect on cooked food until chipping or cracking occurs and the food gets into the cracks, where it is hard to remove by washing. This may cause an unsanitary condition and, since the food is in more intimate contact with the enamel, greater absorption of the lead.

Enamelware is made by dipping the articles in a solution and placing them in a Gehnrich indirect-heating oven, where they will be baked from three to four hours at a temperature of 400° F. This produces a glasslike glaze over the metal

Ewing Galloway



Enamelware, including graniteware, is considered an excellent material for cooking utensils. The hard, glassy surface is easily cleansed and is not reacted upon chemically by weak acids or alkalies; and consequently foods containing acids, such as tomatoes and fruits, should be cooked in enamelware pans or kettles. Unless subjected to sudden shock, which would cause the cracking or breaking of the enamel, utensils made of this material are very serviceable as well as economical. Enamelware which has become checked with small cracks should be discarded. Every kitchen should include some enamelware.

Utensils made of copper. The pride of the colonial housewife was her kitchen with its open fire and brightly polished copper kettles. From ancient times copper has been used for all types of household utensils and equipment. It was the first metal that man learned to use because it is frequently found in the free state and, being soft, is easily shaped. Because it is low in the displacement, or activity, series, it is easily reduced from its ores. One can imagine its accidental reduction in the campfire of some early man centuries ago. He might have built a fire near rocks containing cuprite (CuO), or copper sulfide (Cu_2S). Hot embers of charcoal (carbon) could have come in contact with this ore, causing the reduction. The chemical equations for these reactions are as follows:

$$CuO + C \longrightarrow Cu + CO\uparrow$$
$$2\,Cu_2S + 3\,O_2 \longrightarrow 2\,Cu_2O + 2\,SO_2\uparrow$$
$$Cu_2O + C \longrightarrow 2\,Cu + CO\uparrow$$

Copper is very malleable and, whether found free in nature or reduced from its ore, is easily shaped into ornaments and utensils. Copper implements and utensils have been found that date back as far as six thousand years.

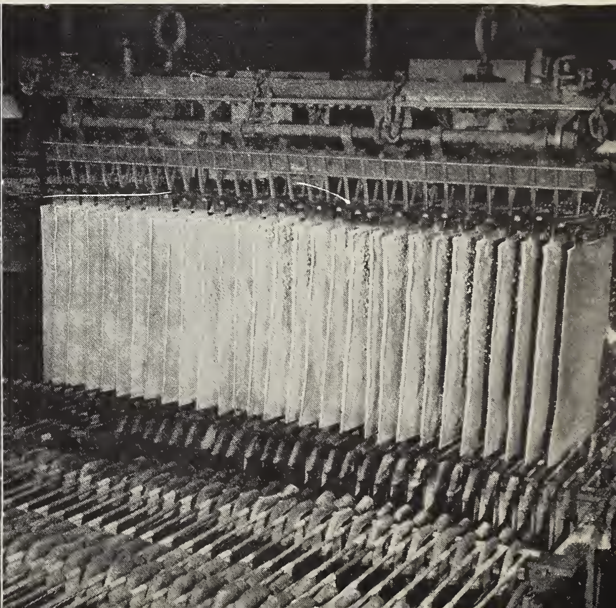
Copper has several physical properties which caused it to be widely used for cooking utensils until recently. It is soft, may be polished to a rich, red luster, and is an excellent conductor of heat.

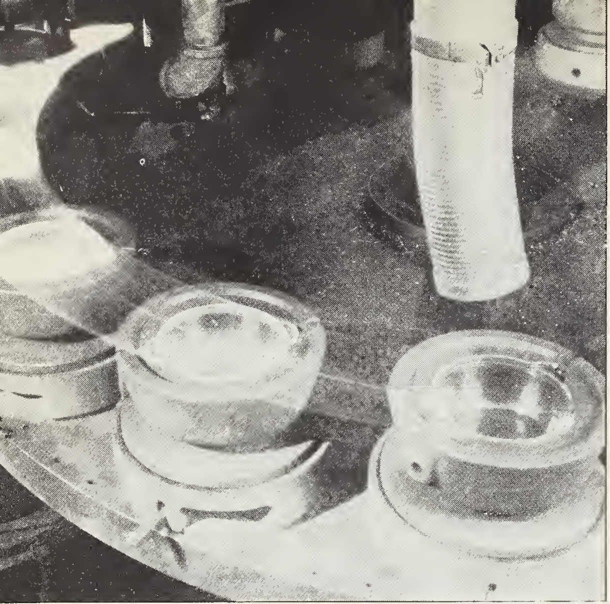
Molten copper being poured from a copper converter at an Anaconda (Montana) copper-smelting plant

Anaconda Copper Mining Company

After copper has been separated from its ores, it is refined electrolytically to remove such impurities as silver, gold, zinc, and arsenic. Plates of crude, or blister, copper are suspended in a solution of copper sulfate and sulfuric acid. These plates are made the anode poles in the solution. The cathodes are thin sheets of pure copper about three feet square. When a direct current is sent through the bath, the copper ions of the $Cu^{++}SO_4^{--}$ travel to the cathode, where they obtain electrons and change to neutral, or free, copper atoms, which become attached to the copper cathodes. The negative sulfate ions travel to the anode, give up their extra electrons, and unite with the copper of the anode to form more copper sulfate. The concentration of the copper sulfate bath remains constant, and the crude copper anode is gradually reduced in size as the pure copper is transferred to the cathode pole. The cathode pole is gradually enlarged as the pure copper is deposited on it. The gold, silver, and other impurities collect at the bottom of the bath as a sludge to be purified later by another process. This picture shows the copper cathodes being lifted from the electrolytic bath

Anaconda Copper Mining Company





Corning Glass Works

"Pyrex" brand ovenware in the making. The molten glass drops into the molds and is automatically pressed into shape by a plunger

Copper utensils have fallen into ill repute during the last hundred years for several reasons. Copper compounds are poisonous. There is little danger if the utensils are kept bright and untarnished, but the housewife of today has not the necessary time or energy to keep them spotless and bright.

From its place in the activity series, you would probably think that copper would be unaffected by most corrosive agents. However, though copper is below hydrogen in the activity series and does not react with dilute acids, it does react with organic acids in the presence of air. Basic copper acetate, known as verdigris, is one of the poisonous copper salts formed in this way.

In many large hotels and hospitals there are immense steam-jacketed boilers made of copper. These are usually plated with tin.

Probably the ordinary housewife will not care to pay the relatively high price of copper utensils. Such vessels are often copper on the outside and plated on the inside with some nonpoisonous metal. Care should be used in cleaning such utensils not to scratch through the plate. Food should not be allowed to stand in copper containers.

Utensils made of glass. Another one of the marvels of modern chemistry is the production of a kind of glass which can be put directly over a flame. We are all more or less familiar with glass and know that one of its properties is that it cracks when subjected to sudden changes in temperature. Yet the chemist has given us heat-resisting glass, which does not exhibit this property. To understand why this is true, we shall first have to look into the chemical nature of glass.

Common glass is made by fusing the oxides of silicon, calcium, and sodium. The fusion takes place at a temperature of about 2500° F. Under this intense heat the oxides combine to form what are known as silicates. We say, then, that glass is a mixture of various silicates. An equation for making glass from sand (SiO_2), limestone ($CaCO_3$), and soda ash (Na_2CO_3) might be written as follows:

$$2\,SiO_2 + Na_2CO_3 + CaCO_3 \longrightarrow \overbrace{Na_2SiO_3 + CaSiO_3}^{\text{glass}} + 2\,CO_2$$

When the mixture cools, after proper heat treatment, called annealing, the silicates form a solid solution without crystallization. Crystallization may occur after a long time, causing cloudiness and brittleness.

Such glass has the disadvantage of a high coefficient of expansion (that is, it expands greatly when heated), so that it breaks easily when it is subjected to changes in temperature. Therefore, to overcome this characteristic, the glass chemist must substitute other minerals for the common ones.

Hard glass may be made by using potassium oxide instead of sodium oxide. Flint glass, for cut-glass ware, is composed of barium, lead, and potassium silicates. These substances improve the qualities of glass to a certain extent, but the real improvement from the standpoint of cooking came when boron oxide (B_2O_3) was substituted for some of the silicon dioxide. This produced a glass which is a mixture of silicates and borates. "Pyrex" glass is a trade name for a similar heat-resisting glass which contains a mixture of sodium and aluminum borates and silicates and free silica. The presence of the borates makes this glass very resistant to heat changes because of its low coefficient of expansion. This type of glass was developed during the first World War and was found to be valuable because of its low degree of solubility and great resistance to temperature changes.

"Pyrex" glass is now used for all kinds of cooking utensils. Even frying pans are now made of it.

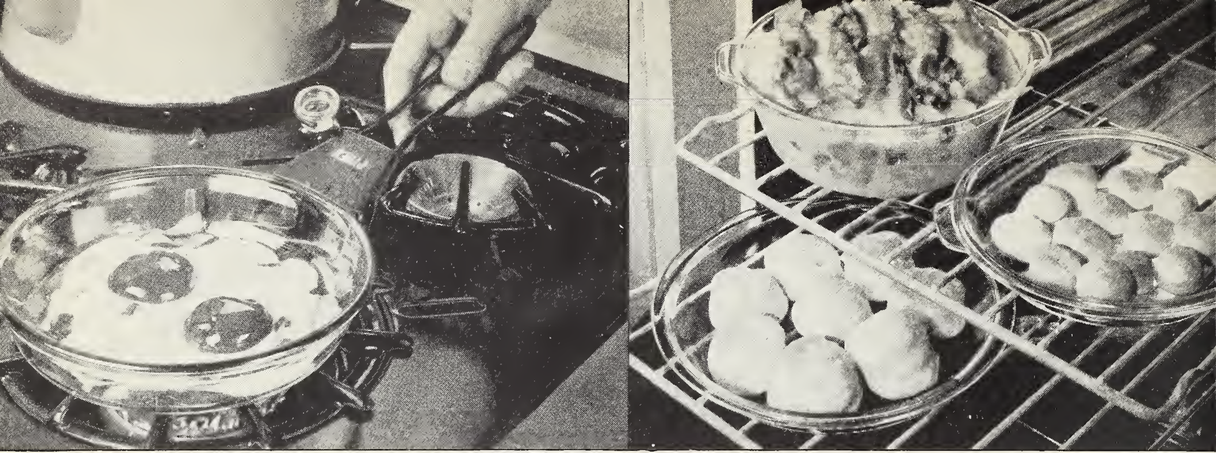
Does glassware make good cooking utensils? The answer to this question is yes. Though most of the other materials used in making cooking utensils react to some extent with many foods, glass utensils do not affect any kind of cooked food. Glassware is easily cleaned; therefore there is little chance of the contamination of food with decomposed material. Foods may be served in the same utensil in which they are cooked. One disadvantage of glassware lies in the fact that it is almost impossible to do "waterless" cooking in it. This is due to its poor conductivity of heat, which causes the food to stick. This disadvantage can be partially overcome by being careful to cook the food in small amounts of water. If not broken, heat-resisting glassware is the most durable of all kitchen-utensil materials. However, since it is breakable, it may prove to be expensive if care is not used in handling it. Glassware as a cooking utensil will probably be used more generally in the household of the future. This will be especially true in time of war, when aluminum, for example, is used in constructing airplanes and other implements of war.

Pottery. Perhaps the oldest form of cooking utensil and food receptacle is that made from clay and hardened by fire. The potter's wheel has been turning for thousands of years and is still used to make many vessels and pots. The first process in the making of pottery consists of grinding dry clay into a powder and then adding water to make a paste. After a pasty mass has been formed, it is shaped by molds or on the potter's wheel. This "green" pottery is then placed in a kiln, where it is thoroughly baked. In order to have a nonporous vessel, salt (NaCl) is thrown into the fuel bed at the bottom of the kiln. The salt vapor reacts with the clay on the surface to form a hard, impervious layer of sodium aluminum silicate.

Porcelain, or chinaware, is made from kaolin, a pure white clay, mixed with powdered feldspar and quartz. The "green" pottery is dipped in a sus-

The sand and other materials of which glass is made are melted together (at the left). A large sheet of glass, formed by the solidifying of molten glass, is shown below (at the right)

The Pittsburgh Plate Glass Company



Corning Glass Works

These two pictures show a modern use of glassware. Why does not the "Pyrex" frying pan break, since the flame is touching it, as shown?

pension of finely ground kaolin, feldspar, and quartz and certain metallic oxides. The glaze which is formed is hard and noncorrosive. When properly made, pottery will stand a great deal of heat and may be used where a gradual, even heat is supplied. For this reason, many baking dishes, both large and small (for individual use), are found in many homes. Many housewives prefer to serve food on the table in the vessel in which it is cooked, thus retaining most of the heat. The earthenware or heavy glass casserole with a closely fitting cover and no steam outlet may be successfully used in the so-called waterless method of cooking vegetables. The cover should fit tightly and should not be removed during the cooking. A moderate temperature should be used to prevent burning. In this way, steam is generated slowly from the water in the food itself. If the vegetables are rather dry, a little water may be added with the same results.

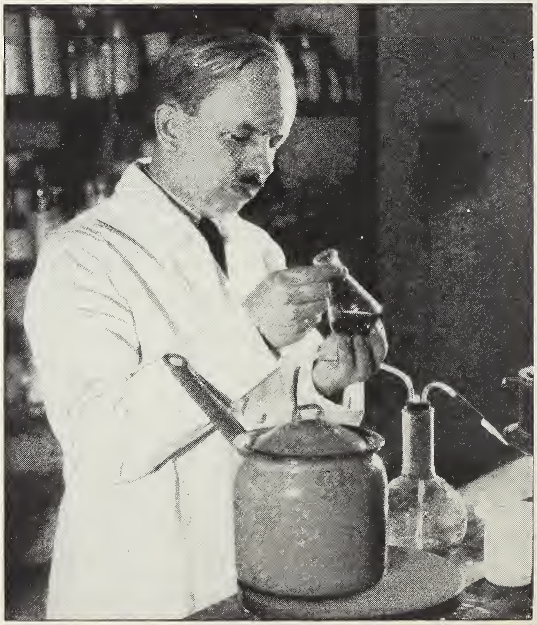
This form of cooking utensil has found favor in many homes; and when it is brought to the table in a metal casserole-holder, it makes an attractive table piece.

What factors should influence the housewife in selecting cooking utensils for her kitchen? From this study of cooking utensils it should be evident to you that the well-equipped kitchen should contain utensils made of more than one kind of material.

Care should be exercised by the housewife in the selection of cooking utensils for her kitchen. She should consider such factors as the utility of the vessel, the hazards entailed in its use, its care, the purpose it is to serve, the desirability of the material of which it is made, and its cost. This requires a scientific discrimination in selection. The scientific attitude may as well be exercised by the housewife as the man in the factory. In fact, the housewife in her daily duties about the house has more occasion for the exercise of scientific judgment than most men in their routine jobs in factories and stores.

This scientist is testing kitchen cooking ware to determine its durability and its effect on food

Good Housekeeping Institute



EXERCISES

1. What changes have occurred in the use of kitchen equipment in the last fifty years? in the last ten years?

2. Why should you know the applications of chemistry in the making and using of cooking equipment?

3. Classify and describe the important facts that you should know about cooking utensils.

4. Describe how aluminum is extracted from its ore.

5. Would you say that Charles Hall discovered aluminum? Why or why not?

6. Draw a diagram of the electrolytic process for obtaining aluminum. Show by equations how the aluminum is separated.

7. What is the effect of aluminum on foods?

8. How should aluminum be cared for?

9. Write the equation for the "pickling" of iron.

10. How is iron plated with tin?

11. Compare the various kinds of materials used for the making of cooking utensils as to utility, effect on foods, and attractiveness.

12. What is enamelware?

13. Write the equation for the production of glass.

14. (*a*) How much glass could be made from 120 pounds of sand? (*b*) How much limestone and washing soda would be required?

15. How does heat-resisting glass differ from ordinary glass in composition and utility?

16. How does porcelain differ in composition from glass?

PROBLEMS FOR FURTHER STUDY

1. Make a detailed cost study of the cooking utensils needed to equip an ideal kitchen completely.

2. Write to various companies that make cooking utensils and assemble information regarding the methods by which the utensils are manufactured.

3. Make a study of the historical development of cooking utensils and report your findings to the class.

4. Make a collection of the advertisements of cooking utensils and compare the claims which are made with the actual facts that you have learned or can experimentally verify.

UNIT EXERCISES

In the statements which follow there are blanks to be filled. On a separate sheet of paper write whatever is necessary to fill the blanks correctly. Do not write in this book.

1. The modern kitchen should be supplied with --(?)-- kinds of --(?)-- utensils.

2. Glass is made from sand, which has the formula --(?)--; limestone, --(?)--; and washing soda, --(?)--.

3. Glass is a mixture of --(?)--.

4. Iron is undesirable as a material for cooking utensils because it --(?)-- easily.

5. One should know how different cooking utensils --(?)-- foods.

6. --(?)-- discovered the modern way of obtaining aluminum.

7. Aluminum is obtained from the ore known as --(?)--, which has the formula --(?)--.

8. Aluminum is obtained by the --(?)-- method.

9. --(?)-- foods should not be cooked in aluminum utensils.

10. --(?)-- or rolled aluminum makes a very desirable cooking utensil.

11. Before iron is plated it must first have the --(?)-- removed by treating it with --(?)-- acid.

12. A thin coating of --(?)-- which accumulates on iron cooking utensils usually prevents much --(?)--.

13. Utensils used in the home such as --(?)-- and --(?)-- are made by galvanizing iron.

14. Galvanized iron is made by coating iron with --(?)--.

15. The enamel coating on enamelware has a composition similar to that of --(?)--.

16. Copper is --(?)-- hydrogen in the activity series.

17. --(?)-- acids will oxidize copper in the presence of air.

18. Cu_2O + --(?)-- $\longrightarrow$ --(?)-- + $CO\uparrow$.

19. --(?)-- glass can be made by mixing --(?)-- oxides with the other ingredients used in ordinary glassmaking.

20. Chinaware is made from --(?)--, feldspar, and quartz.

REFERENCES FOR FURTHER READING

MacLeod, Annie L., and Nason, Edith H. *Chemistry and Cookery.* McGraw-Hill Book Company, Inc., New York, 1930.

Naylor, Nellie M., and Le Vesconte, Amy. *Introductory Chemistry with Household Applications.* D. Appleton-Century Company, Inc., New York, 1933.

UNIT 22

The Chemistry of Tableware

The fragments of earthen bowls in prehistoric ruins prove that early man made use of crude vessels for the storage and preparation of food. These bowls were fashioned from clay and baked in his campfire. Perhaps he used shells for spoons and sharp-edged stones for knives. The knives were used to cut the meat into smaller chunks; but often he had no need for them, since he used his fingers instead. Forks were unknown. They are of comparatively recent origin. In fact, there was considerable religious prejudice against their use for a long time. It was argued that God had given man fingers with which to eat and that the use of any device to take their place was sacrilegious. Later it was considered effeminate for a man to use a fork.

As metalworking was perfected, knives, spoons, and, later, forks came into use. Only the wealthy could afford them at first, and each individual carried his own about with him. As metalworking became more productive, the ordinary man had his individual knife of inexpensive metal, while the nobility had spoons of silver and gold and knives with ornamental handles.

Man's desire to decorate his belongings caused him to decorate his earthenware and to seek better methods of manufacturing it. The early Chinese invented the method of making porcelain, or china. The introduction of porcelain into western Europe fostered the development of the fine-chinaware industry there.

Early use of tableware has helped man to improve his standard of living

Today the housewife is thrilled as she goes through the chinaware and tableware department of a large store. Beautiful silver service and exquisitely decorated chinaware greet her eyes. To the modern homemaker utility seems to have become of secondary importance; instead she is more interested in the beauty of design and the coloring of her tableware.

Behind the beauty of pattern and coloring lies man's ingenuity in taking crude raw materials and chemicals and, with them, producing articles of charm and service.

PURPOSES TO BE ACHIEVED

1. To learn how tableware is made.
2. To determine the factors which should be considered in the selection of tableware.
3. To learn how to care for and to clean tableware properly.
4. To learn how to purchase tableware economically.

PROBLEMS TO BE SOLVED

1. How is silverware made?
2. How may you buy plated silverware intelligently?
3. How should silverware be polished and cared for?
4. How is dinnerware made?

Problem 1. How is silverware made?

Kinds of silverware. Silverware and other metal tableware may be classed as flatware and hollow ware. Flatware consists of knives, forks, and spoons; hollow ware consists of bowls and other vessels.

Silver is a fairly soft, white metal which is capable of a high polish. It is often found in the free state. Silver is also found mixed with the ores of copper, gold, and lead. A common ore of silver is Ag_2S.

Since silver occurs in the free state and is easily extracted from its ores, it is one of the oldest metals known and used by man.

The purest form of silver used in tableware is called sterling silver. Its standard composition, fixed by law, is 92.5 per cent silver and 7.5 per cent copper. Silverware is made by molding the object from molten metal or, more often, by rolling and stamping the object from sheet silver. The design is usually "struck" upon the metal by a die, though it may be etched or hammered.

Sheffield plate, a kind of silverware, may be made by rolling, into a thin sheet, silver and copper which have been soldered together in the form of a bar. It is more common today to make it by electroplating the silver on the copper after the object has been shaped.

Most tableware sold today is silver-plated. Plated silverware is made by first stamping the knife, fork, or spoon from a metal which is cheaper than silver. This metal may be German silver, which contains no silver at all but is 52–60 per cent copper, 1–22 per cent nickel, and 25 per cent zinc, or, more generally, sheet iron or steel. The article is then plated with silver by an electroplating process.

How is tableware silver-plated? After the object, such as a knife, fork, or bowl, has been shaped from the inexpensive metal, it is given a coat of silver by a process called electroplating. The object must be perfectly clean; otherwise the silver will not stick to the metal. In the picture at the top of page 348 forks are being silver-plated. The solution in the

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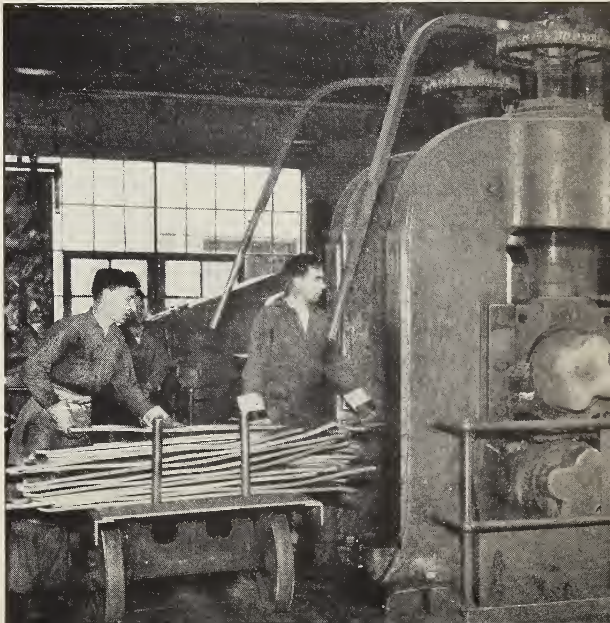
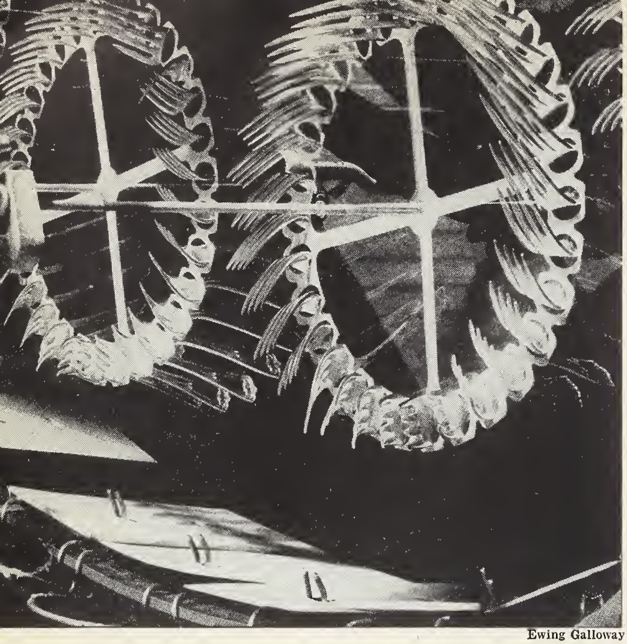
Rolling metal bars into sheets of metal before stamping out knives, forks, and spoons. Slabs of nickel silver, weighing 90 pounds each and measuring about $1\frac{1}{4}$ inches in thickness, are passed through two 6000-pound steel rolls. The bars of metal are reduced to sheets of proper thickness for the making of spoons, forks, etc. After the individual pieces are stamped in rough form, the designs are stamped on them. The pieces are then ready to be plated with silver

Ewing Galloway





Ewing Galloway

Electroplating forks. The thoroughly cleaned forks, which are made of some base metal, are placed on revolving racks in the tank. On the sides of the tank are placed bars of pure silver. Silver cyanide solution is placed in the tank to cover the forks and the bars of silver. The forks are made the cathode poles, and the bars of silver the anode poles. When an electric current is run through the solution, silver ions travel to the cathode poles (forks) and are deposited as free silver. Cyanide ions travel to the anode poles (bars of silver), where they cause the silver atoms to lose electrons and become ions of silver. This process is allowed to continue until the desired thickness of silver is obtained. The forks are then polished

vat, the electrolyte, is a special solution of a silver salt, usually silver potassium cyanide ($KAg(CN)_2$). The forks are made the cathode (negative electrode) by attaching them to the negative terminal; the anode (positive electrode) is bars of silver, which are also suspended in the solution. Direct electric current, or unidirectional current, must be used.

When the current of electricity passes through the solution, the positive ions of silver in the solution are attracted to the negative pole, the forks. As soon as the silver ions touch the forks, they give up their electric charge and become attached to the forks as atoms of free silver. As these ions become atoms, an equal number of atoms of silver from the anode give up electrons and become ions, which go into the solution, thus maintaining a constant concentration of the electrolyte.

The amount of plating that an object will receive depends on the strength of the current and the length of time that the object is left in the solution. Thus tableware that is to be heavily plated has a stronger current applied to the solution and remains in the solution longer than ware that is to be lightly plated.

Gold-plating, nickel-plating, and chromium-plating are carried out in a similar manner. The electrolyte in each case is a salt of the metal to be plated, and the anode is a bar of the same metal. Plating with gold, nickel, and chromium is not as simple as it may seem, as many factors enter into the process. Other chemicals, many of which are kept secret by manufacturers, are added to the electrolyte to aid in the electrolysis.

After the object has received a sufficient coating of silver, it is thoroughly washed and polished to a bright finish. Some hollow ware, particularly objects which will not need to be washed in the home, are covered with a thin coating of lacquer to preserve the bright finish and prevent tarnishing.

EXERCISES

1. Why do archaeologists frequently find decorated pots and bowls in prehistoric ruins?
2. What purposes do chinaware and silverware serve?
3. Why should you study tableware in a chemistry class?

Chemistry has played a large part in making it possible for the modern housewife of modest means to lay a perfectly appointed dinner table

International Silver Company

4. What is the difference between flatware and hollow ware?
5. What is sterling silver? How is it made?
6. Explain the electrolytic method of silver-plating.

Problem 2. How may you buy plated silverware intelligently?

Many grades of plated silverware make wise buying difficult. Silver-plated flatware is made in many grades according to the thickness of the plate. The government has set up certain standards for plated flatware. The following table shows the many grades of silver-plating recognized by the government:

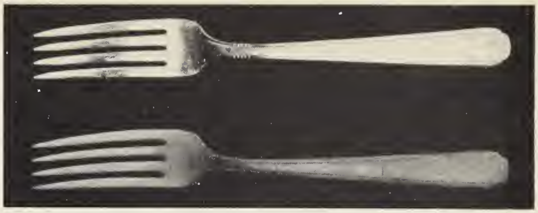
Plate	Ounces of Silver per Gross	
	Dinner Fork	*Dessert Spoon*
Quadruple, or xxxx	16	12
Triple, or xxx	12	9
Double, or xx	8	6
AA	6	4½
A1 +, or Extra	4 + reinforcement	3 + reinforcement
A1, or Standard	4	3

However, this is not an infallible guide to be used in the selection of flatware, as some manufacturers do not give such specifications, contending that the method of applying the plate is more important than the thickness of the plate. Be this as it may, in general we may regard it as true that the thicker the plate is, the longer the life which may be expected of the silverware. But no matter how superior the grade of silverware, it is bound to wear, more or less according to how often it is used and how much care we bestow upon it.

The better grades of flatware contain reinforcements at the points of greatest wear. The reinforcements are made either by inlaying blocks of silver or by overplating at these points of wear.

Housewives will find that they will add years to the life of their best silverware and preserve its beauty if a cheap set of flatware, made of German silver or stainless steel, is purchased for ordinary use.

Silverware purchased in sets is more economical than that purchased by the piece. If the set has more pieces than are in constant use, they should be used in rotation so that they may wear evenly.



Consumers Union

When the silver has been stripped from a silver-plated fork, only the thin bright coating is removed. The base metal (below) shows the details of the pattern

Knife blades should be made of stainless steel. This steel contains the metal chromium. It resists the corrosive action of fruit juice and other foods.

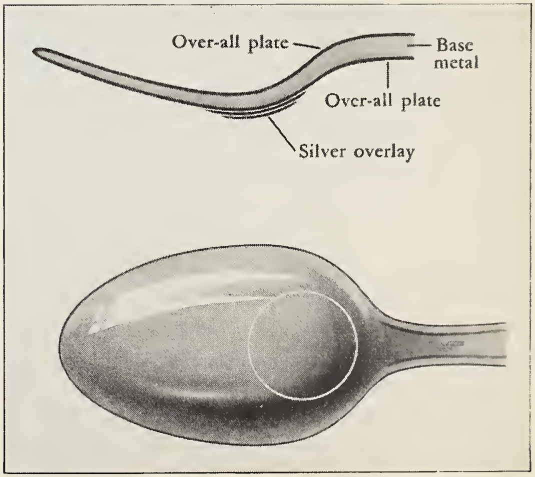
EXERCISES

1. What is quadruple-plated silverware?
2. Does the label "A1 +," or "Extra," designate a good grade of plated silverware?
3. How can you buy silverware intelligently?

Problem 3. How should silverware be polished and cared for?

General care. Silverware should be stored where it is protected from continued exposure to moisture and impurities in the air. Many sets of silverware come packed in chests which are so made that they

The top diagram illustrates how the extra silver on a fork is applied over the area of the greatest wear — where the tines rest on the table. The bottom diagram shows overlay reinforcement on a spoon



Silver may be cleaned by electrolysis. Place the articles to be cleaned in an aluminum pan. Add boiling water to cover the silver; then stir in the water 1 teaspoonful of baking soda and 1 teaspoonful of common salt. In a few minutes the silver will be clean. What advantage has this chemical method of removing tarnish over that of rubbing?

can be shut tight. Flatware should be kept in these chests, though there may be scratching of the pieces, since they nest in contact with one another. They are better protected if wrapped separately in a soft cloth.

Silverware should never be allowed to stand overnight before washing, since this practice invites tarnishing. Moreover, since food soon dries on silverware, it is harder to clean after it has stood awhile, and there is more danger of scratching the finish when it is washed. Silverware should be washed in hot, soft water with a neutral soap, rinsed with hot water, and dried with a soft cotton cloth. Care should be used in washing to prevent scratching. Knives and forks should be washed separately and placed on a cloth separately to dry. Hollow ware should never be piled in the dishpan, but each piece should be washed separately.

Lacquered pieces should not be washed, as water causes them to peel. If they do peel, alcohol will remove the rest of the lacquer, and the pieces may be refinished with a new coat of clear lacquer.

What causes silverware to tarnish, and how may tarnish be removed? Silver is relatively low in the displacement series and is not easily corroded. It does not oxidize in air to form an oxide. The brownish or black tarnish which often occurs on silver articles is its sulfide (Ag_2S), which forms when the metal comes in contact with foods containing compounds of sulfur or is acted upon by air containing hydrogen sulfide (H_2S). Eggs or foods prepared with eggs contain sulfur compounds and easily tarnish silver. In regions where a great deal of coal is burned, silver tarnishes rapidly because of the sulfides present in the smoke of the atmosphere. When silverware is wrapped for storage, a rubber band should not be used to secure the wrapping. Rubber contains sulfur, which will cause the silverware to tarnish.

Electrolytic silver-cleaning devices. There are many commercial devices on the market for the removal of tarnish from silver. Some are often called electrolytic silver-cleaners. One such type consists of a special pan containing an aluminum sheet or tray. Sometimes only a sheet of aluminum is sold, with directions for its use. The silver articles are placed in the pan in contact with the aluminum sheet, and the pan is filled with a warm solution of baking soda ($NaHCO_3$) and salt ($NaCl$). The solution is then allowed to boil. The articles are left in the solution until the tarnish disappears, then removed, rinsed, dried, and polished. It is unnecessary to buy the electrolytic metal sheets, as the same results can be obtained if the silver is placed in any aluminum pan and the solution added as described above. This process of cleaning silverware does not remove or injure the silver in any way.

The chemical reactions which take place in the solution mentioned above are rather complex. Aluminum is higher in the activity, or electrochemical, series than silver. Consequently it is more highly electropositive than silver and tends to displace the silver from silver compounds.

The equation for the removal of silver tarnish is as follows:

$$3\,Ag_2S + 2\,Al \longrightarrow Al_2S_3 + 6\,Ag$$

The sodium chloride in the solution acts as an electrolyte, enabling the exchange of atoms to take place as shown in the equation.

The baking soda ($NaHCO_3$) reacts with the aluminum sulfide as fast as it is formed. This removes the aluminum sulfide from the article, causing it to go into solution. The sodium sulfide formed is also soluble. The equation for this reaction is as follows:

$$Al_2S_3 + 2\ NaHCO_3 + 4\ H_2O \longrightarrow 2\ Al(OH)_3 + Na_2S + 2\ H_2S\uparrow + 2\ CO_2\uparrow$$

The $Al(OH)_3$ and Na_2S are soluble in the alkaline solution.

Silver polishes. There are a number of silver polishes on the market, and the housewife is often puzzled about which to select. Silver polishes should contain no grit. The removal of the tarnish is due to the abrasive action of some material such as whiting, powdered pumice stone, rotten stone (a decomposed limestone containing silica), or rouge. Commercially the polish is made by mixing one or more of these with soap and water. Some commercial cleaners contain sodium bicarbonate, wax, glycerin, or hypo (sodium thiosulfate). The function of the soap and soda is chiefly to act as a cleaner by removing the grease and dirt from the surface of the silver. They do not have much effect on the tarnish. This is removed through the scouring action of the abrasive. The coarser the abrasive, the more rapid its action. However, a coarse abrasive will remove a considerable amount of silver. It follows, then, that a rapid-acting polish is not the best. The housewife should test commercial polishes by rubbing a little of each type over the fingers or fingernails and should select the one containing the least amount of grit.

Silver polishes containing cyanide compounds are very poisonous and should not be used. Tarnish preventives are chemicals used in silver chests to remove the sulfur compounds from the enclosed air. They are effective only when a chest is kept tightly closed.

The housewife may find it more desirable and safer to make her own silver polish. This may be done by purchasing a small amount of an extra-fine grade of whiting from a paint store. A paste can be made by mixing the whiting with a little household ammonia, powdered neutral soap (such as castile), and water. This polish may not be so rapid in action as commercial polishes, but there will be less danger of scratching the silver. Since this polish becomes hard rather rapidly, only the amount needed should be made into the paste. A polish which keeps longer may be made by the following formula:

3 level tablespoonfuls of powdered neutral soap
$\frac{1}{2}$ ounce of glycerin
$1\frac{1}{2}$ ounces of hot water
1 teaspoonful of household ammonia

The mixture should be stirred well, and a sufficient amount of an extra-fine grade of whiting should be added to make a firm paste. The polish should be kept in a tightly closed container.

A soft flannel cloth should be used to apply the polish. The silver should be rubbed until clean, then wiped free of polish with another soft cloth, washed with warm water, rinsed, and dried.

EXERCISES

1. How should silverware be stored?

2. How should silverware be washed?

3. How should lacquered hollow ware be cared for?

4. What substances cause the tarnishing of silverware?

5. What foods are most likely to cause the tarnishing of silverware?

6. How may you polish silver by the electrolytic method? Write the equations for the process.

7. What do silver polishes contain? How do they work?

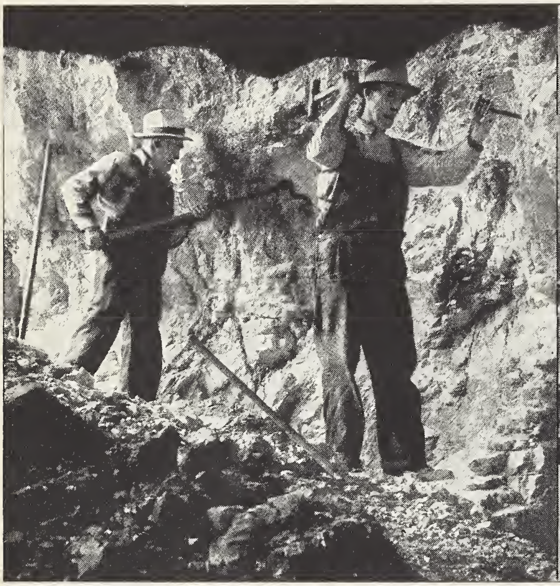
8. How can you make your own silver polish?

Problem 4. How is dinnerware made?

Where did chinaware originate? Chinaware, or porcelain ware, was first made by the early Chinese. A crude quality of porcelain ware was made by the Assyrians, Egyptians, Babylonians, and Greeks. Indeed, all early peoples were masters of the art of making pottery. However, the Chinese were the first to bake a clay dish with a hard body and a beautiful glaze. Many times a beautiful color design was embodied in the glaze. In modern times porcelain is produced in many of the European countries, notably England, Germany, France, and Italy, and in the United States.

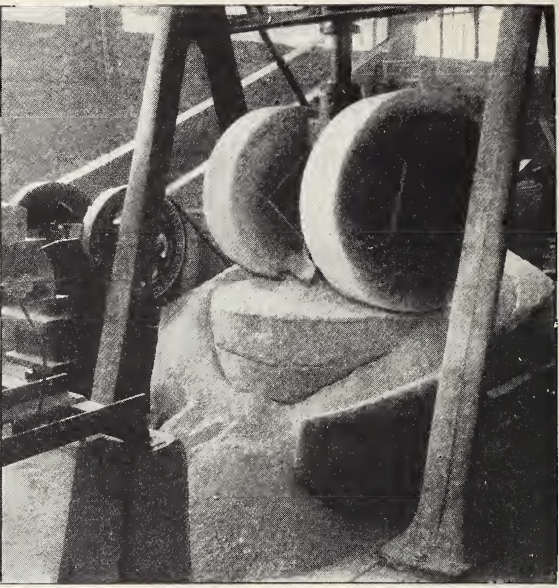
How are dishes made? The base material of porcelain dishes is clay. Feldspar ($KAlSi_3O_8$), sand (SiO_2), ground flint (SiO_2), or bone ash is also added to produce a particular texture. There are many types of clays which may be used. Clay is a mixture of silicates, such as kaolin ($H_4Al_2Si_2O_9$) and feldspar. Often sand is an ingredient, together with traces of metallic oxides. Geologically, these

Making Porcelain Dishes



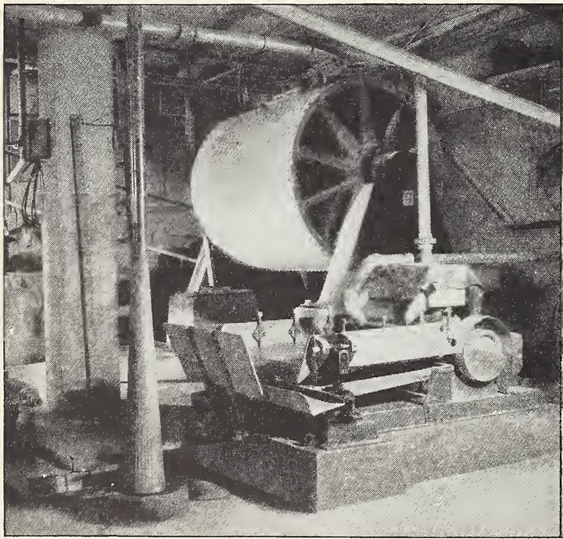
Coors Porcelain Company

One of the chief ingredients used in making dinnerware is feldspar. Here feldspar is being removed from underground mines near Golden, Colorado



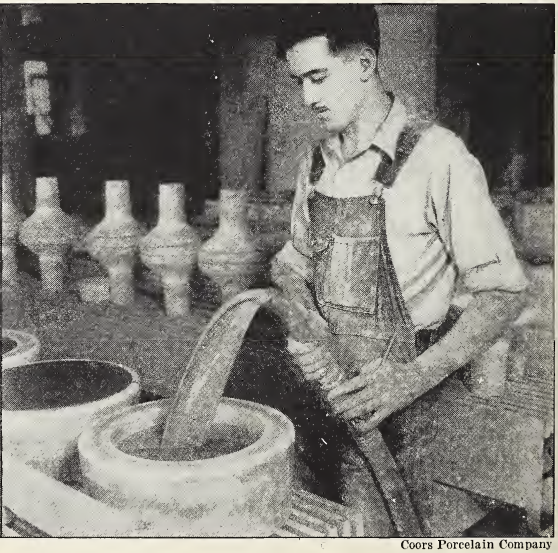
Coors Porcelain Company

The feldspar, clay, and other materials are ground by granite wheels. Iron wheels would cause a discoloration of the finished product



Coors Porcelain Company

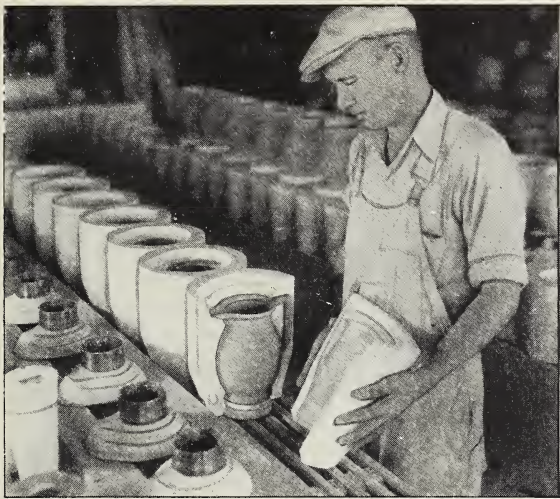
The materials are pulverized in pebble mills—rotating drums which contain hard round rocks. These iron-free rocks are imported from Europe. The materials are then screened through a vibrating shaker before being mixed with water



Coors Porcelain Company

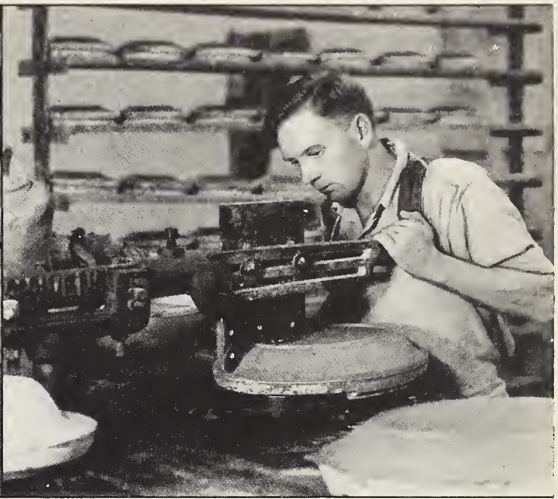
If molded objects are to be produced, enough water is added to make the mixture of ground feldspar and clay thin enough to be poured into plaster-of-Paris molds. This workman is about to cast a pitcher

Making Porcelain Dishes



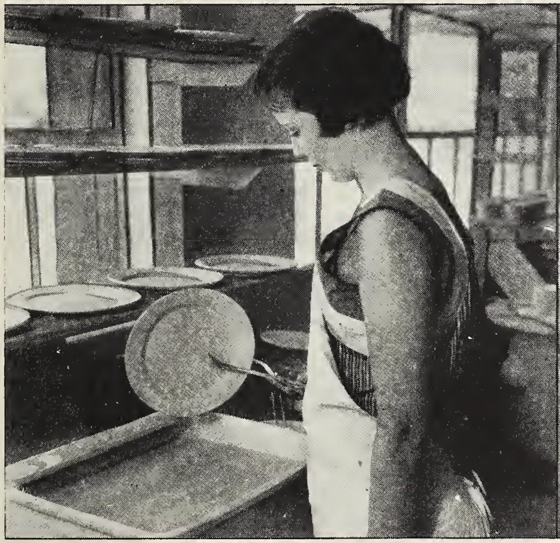
Coors Porcelain Company

After the clay mixture has stood in the plaster-of-Paris mold for several hours, a thin coating of the hardened material will have adhered to the inner surfaces of the porous mold. The excess liquid mixture is poured out of the mold. The thickness of the pitcher is determined by the length of time that the clay mixture remains in the mold



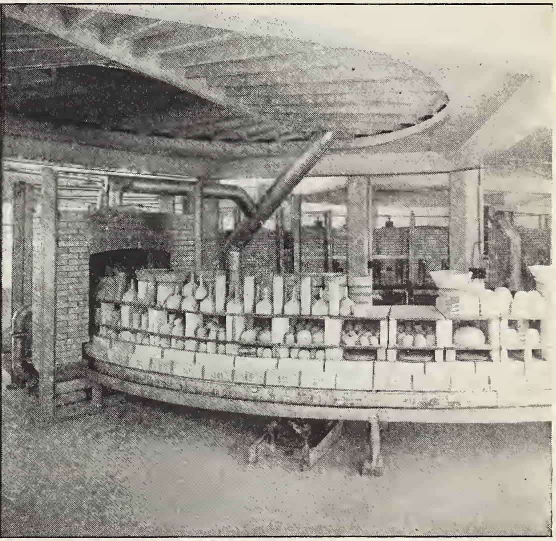
Coors Porcelain Company

Plates are made by placing the clay material on molds such as the one seen at the left. The mold is then placed on a rotating table. The bottom part of the plate is formed when the excess material is removed by stationary knives as the mold turns. The knives form the outside of the plate, and the mold forms the inside. After drying, the plate is ready for its first firing



Coors Porcelain Company

After the preliminary, or biscuit, firing, the plates are dipped in "slip." When the plates are fired with this material on them, they receive a glaze and color



Coors Porcelain Company

The last step in the process of making dishes is the firing of the glaze and color on them. This is often done in a circular continuous kiln, the dishes passing slowly through the kiln substances are formed by the weathering and decomposition of granite. When iron is present in clay, it gives a red or yellow color to the baked articles. Clay containing iron is used in the manufacture of brick and flowerpots.

Clay composed of pure hydrogen aluminum silicate is called kaolin and is white. From it is made our finest white chinaware. The pulverized clay is first mixed with water, after which pebbles and other hard objects are removed by running the mixture through screens. Then the water is removed from the clay, and it is ready to be mixed with the other ingredients which are necessary in the manufacturing of chinaware. The kinds of materials added depend on the quality of the chinaware to be made. One common quality is made by mixing the clay with powdered feldspar and flint. Water is added to the mixture, and it is thoroughly stirred by machinery until it has the consistency of bread dough. The plastic mass is then ready to be shaped into the desired object by means of a potter's wheel or by pressing it into molds.

The dinnerware is dried and then placed in cylindrical cases made of fire clay, called saggers; then these are put in the kiln, and the ware is fired. The saggers protect the dinnerware from the soot and ash of the fire and ensure even heating. The firing lasts from thirty-six to forty-eight hours. When removed from the kiln after this first firing, at about 2250° F, the ware is hard and porous and must be glazed before it can be used. The style of kiln, time of firing, and heat vary with the different grades of ware.

Before firing, the molded articles contain water under two different conditions: (1) water which has been added to make the material sufficiently plastic to be worked and (2) water chemically combined with the clay. The temperature in the kiln is gradually increased to about 2250° F, and the water which was added is driven off. This expulsion causes a shrinkage, and the ware becomes somewhat hard but is not durable. It is only at high temperatures that the water of combination is removed and the ware becomes hard and brittle and will not recombine with water.

How are glazes put on chinaware? The process by which a glaze is put on the articles consists of dipping, spraying, or brushing the articles with a mixture called "slip." This mixture is made by grinding such substances as feldspar, flint, and litharge (lead oxide) to a fine powder and mixing with water to the consistency of cream. After being dipped, brushed, or sprayed with this mixture, the article is left to dry. It is then placed in the kiln and fired a second time to a white heat, which produces a glaze. Glazes vary in chemical composition with the materials used in the "slip." After firing, the ware is hard, smooth, and glassy. The degree of translucency varies greatly.

Since the body of the ware and that of the glaze are made of two different materials, they have different rates of expansion and contraction when heated and cooled. For this reason, the firing and cooling must be done gradually; otherwise the glaze will check, or show minute cracks. Fine china is fired at higher temperatures than ordinary china, and usually the glazed surface does not check.

How are decorations put on china? Decorations may be applied either before or after the glaze and are fired in decorating kilns. If the designs and colors are put on before the second firing, the decoration is called underglaze decoration. When the decoration is applied to the ware after it has been glazed, it is called overglaze decoration. Underglaze decoration is more permanent but is limited in range of color to those colors which can stand the high temperatures to which they are subjected. Certain colors cannot be applied as underglaze decoration, since they change in the firing.

One method of applying designs is to use a lithographed transfer paper called decalcomania. The designs are cut on a lithographic stone, and the impressions are filled with mineral colors in a wax medium. The designs are then transferred to a special paper. This paper is applied to the ware face down and soaked off with water, which leaves the designs on the surface of the dish. The colors are then mixed with a flux to help them to fuse with the ware when fired.

Designs on china may be painted by hand. Since hand-painted colors tend to run together, several firings may be necessary if more than one color is used.

What are the types of dinnerware? The terms *chinaware*, *porcelain ware*, and *earthenware*, which are often used of dinnerware, are used so loosely by manufacturers and retailers that it is impossible to distinguish them clearly. Chinaware and porcelain ware are generally used interchangeably in naming the better qualities of dinnerware, although dinnerware sold under either name may vary greatly in quality. Some retailers call the poorer qualities of dinnerware earthenware, and others use the term *semiporcelain ware*. *Earthenware* is also used in referring to flowerpots and other unglazed articles.

The best quality of chinaware is made from the finest of materials; the workmanship is of the highest quality, and the manufacturing process is very carefully controlled.

Because of the great variations in the quality of dinnerware, it is important that housewives know some of the factors which should be considered in the selection of dinnerware.

How should dinnerware be selected? Dinnerware should be selected on the basis of beauty, durability, and usefulness. The best quality of chinaware is translucent, and when struck with a wooden mallet, it rings clearly. Dinnerware of poor quality is opaque, and when struck, it gives a dull sound. It is always a good policy to examine dinnerware closely for cracked and chipped places. These imperfections may be detected by dropping red ink on the surface. If the glaze is cracked or chipped, the ink will be absorbed and will be hard to remove.

The pieces of the dinnerware should be examined for other blemishes, including irregularities in color or design. Though thin china is very desirable, one should take thought before selecting it for everyday use, for it may be too fragile for such use. The colors should be selected so that they will harmonize with the other home furnishings.

There are usually five grades of wares put on the market by manufacturers. They are selects, first grade, second grade, third grade, and culls, or lumps. Only selects contain no blemishes. First and second grades may have slight blemishes which are not easily observed.

The consumer can place little faith in the statement that a certain pattern is in open stock. All imported ware must bear the name of the country in which it is made. Unmarked ware is made in the United States.

How are different types of glass made? Glass is used in many places in the modern home. For ex-

Corning Glass Works

This skilled glass-blower is blowing a laboratory flask in an iron mold

Intricate laboratory glassware is still blown by mouth. Complicated machines now blow thousands of bottles and other glass articles mechanically in a fraction of the time that it formerly took to blow these articles by mouth

Corning Glass Works

ample, it is used for dinnerware, electric-light bulbs, bottles, glasses, jars, mirrors, and windows. You have already learned that ordinary glass is made from sand (SiO_2), sodium sulfate (Na_2SO_4), sodium carbonate (Na_2CO_3), and calcium carbonate, or limestone ($CaCO_3$). Many different types of glass, with varying properties, may be made by adding or substituting other metallic compounds.

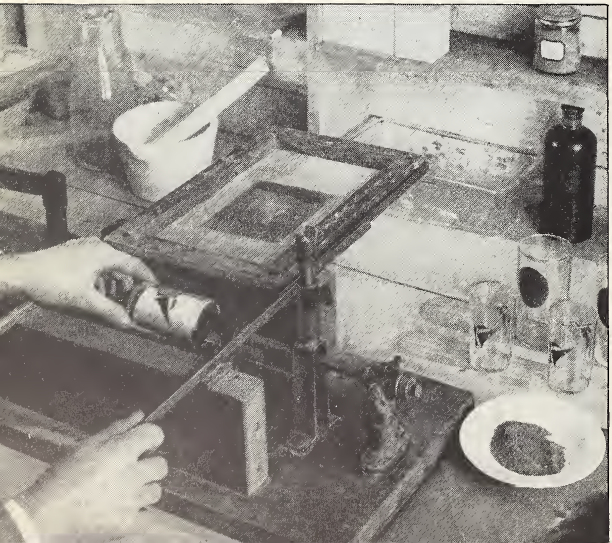
Ordinary, or soda, glass is the softest, most easily worked, and cheapest glass. From it are made bottles of all types, cheap dinnerware, and ordinary window glass. The substitution of potassium for sodium and of lead for calcium gives a much harder and more brilliant glass. This type of glass is used for the manufacture of fine tableware, such as cut glass. It is also used in making optical and camera lenses.

Molten glass is poured into molds or may be blown by mouth to the desired shape. Formerly all bottles, jars, and other ordinary glass vessels were blown by mouth. Now, however, automatic machines turn out thousands of articles each hour in the large glass factories.

Iron compounds usually occur in sand and give glass a green tint. This can be seen by looking at the edge of a piece of window glass. This green color may be lessened by adding manganese dioxide to oxidize the ferrous iron to ferric iron, which imparts only a slight yellowish tint to the glass.

Chemists are continually experimenting to produce better methods and more beautiful and durable colors in the ceramics laboratory. This chemist is printing a design on a glass through a silk-screen stencil in order to test the suitability of the colors that he has developed for this type of decoration. A similar method is used on a large scale in decorating glasses and other glassware

E. I. Du Pont de Nemours & Co.



E. I. Du Pont de Nemours & Co.

This small gas-heated kiln is used by the research chemist to fire the glassware and porcelain ware in order to test the colors that he has used in decorating the objects

Colors in glass are obtained by adding colored mineral salts or oxides to the molten glass. Designs on glass dinnerware are obtained by molding, cutting, sanding, or etching. The molds, into which the molten glass is poured and blown, may have designs imprinted or overlaid. Thus the ware has a design on it when cooled. Glass may be cut with emery wheels or other abrasives. A fine stream of sand blown against a glass vessel may be used by a skilled workman in cutting designs.

The etching of glass is done by first covering the article with wax. The design is cut in the wax so that the glass surface is exposed. Hydrofluoric acid (HF) or the fumes of this acid are allowed to come in contact with the exposed glass. This acid reacts with the glass, cutting the design which had been previously made in the wax. The wax is then removed, and the glass is left with the etched design.

Light bulbs are frosted on the inside by injecting a stream of hydrofluoric acid into the bulb and then washing thoroughly with water.

How are mirrors made? There are two processes used in silvering mirrors—the Rochelle-salt process and the Brashear process. Both are based on the precipitation of free silver by the reduction of silver salts. The reduction is made to take place on glass, so that the silver sticks to the glass.

In the Rochelle-salt process two solutions are used—one of silver nitrate ($AgNO_3$) and aqua ammonia (NH_4OH) and the other of silver nitrate and Rochelle salt ($KNaC_4H_4O_6$). A piece of plate glass, previously cleaned, is suspended in the first solution, and the Rochelle-salt solution is added. The reduction of the silver nitrate by the salt solution causes the free silver to deposit on the glass, forming a mirror. The silvered surface is then dried and polished. Lacquering or painting the surface protects and preserves the silver coating.

In the Brashear process the reducing solution is made of sugar, alcohol, and nitric acid, and the silvering solution is a mixture of silver nitrate and potassium hydroxide.

Cheaper mirrors are made from ordinary window glass with a thin coat of silver. Plate glass with a thick silver surface makes the best mirrors. Before purchasing a mirror, inspect it carefully by looking through the glass for flaws in the silver surface.

EXERCISES

1. What substances go into the making of dishes?

2. How does fine chinaware differ from cheap pottery?

3. Describe the process of making dinnerware.

4. Describe the kilns in which dinnerware is fired.

5. What is "slip"?

6. How are colored decorations put on dinnerware?

7. What grades of dinnerware are manufactured?

8. How is glassware for table use manufactured?

9. How is colored glassware produced?

10. What causes common glass to have a greenish tint?

11. What substances are used in the etching of glass? How is etching accomplished?

12. Explain the process of making mirrors.

13. Why does a piece of glass with a coating of silver form a mirror?

14. What are the differences between a poor mirror and a good one?

Designs are etched on glass by covering the object with wax. Then the design is cut through the wax by hand or machine, and the exposed glass of the design is treated with hydrofluoric acid to produce the etching. This workman is cutting the markings through wax on a glass measuring cone preparatory to etching

Corning Glass Works

PROBLEMS FOR FURTHER STUDY

1. Make a study of the early history of glass.

2. Make a list of the uses of glass.

3. How is stained glass made?

4. What is spun glass, and how is it used?

5. What is glass wool, and how is it used?

6. Make a list of the mineral salts used to produce the various colors in glass.

7. Make a list of the various glass dishes used in the home.

8. What kinds of glass vessels may be used in the kitchen? Explain why a glass skillet does not break when used on the stove.

9. What are flint glass and crown glass?

10. What is meant by tempering glass in the manufacturing process?

11. What is rock crystal?

12. Explain why lead glass is more dense than ordinary glass.

13. Why does good cut glass give a metallic ring when struck suddenly?

14. Why should glass dishes be tempered by being warmed before hot liquids are poured in them?

15. Why is a metal fork or spoon placed in a fruit jar before something hot is poured into it?

16. Why will glasses sometimes break if hot water is poured into them?

UNIT EXERCISES

The statements which follow are incomplete. On a separate sheet of paper write whatever is necessary to complete each statement. Do not write in this book.

1. Earthenware bowls and pots were used in --(?)-- times.

2. The making of dinnerware and the making of silverware are --(?)-- processes.

3. Silverware is desirable because it is possible to obtain a --(?)-- polish on it.

4. Sterling silver contains --(?)-- and --(?)--.

5. Silver is a metal which is sometimes found in the --(?)-- state.

6. German silver contains --(?)--, --(?)--, and --(?)--.

7. Most silverware is --(?)-- by the --(?)-- process.

8. In the electroplating of silverware the object to be plated is made the --(?)--, and --(?)-- bars are attached to the --(?)--.

9. In the electroplating of silver, the electrolyte is --(?)--.

10. A --(?)-- electric current is used in electroplating.

11. Hollow ware which has been plated is sometimes covered with --(?)--.

12. The best quality of plated silverware is usually --(?)-- plated.

13. Silverware should be stored in --(?)-- chests.

14. The tarnish which forms on silverware has the composition --(?)--.

15. Foodstuffs containing --(?)-- will easily tarnish silver.

16. Silver may be polished electrolytically by placing it in an --(?)-- pan containing a warm solution of --(?)-- and --(?)--.

17. Silver is --(?)-- in the electrochemical series than aluminum.

18. Silver polishes should contain no --(?)--.

19. The principal ingredient in chinaware is --(?)--.

20. Feldspar, a complex silicate of --(?)--, is also used in making dishes.

21. The presence of iron in clay gives a --(?)-- color to pottery made from such clay.

22. Dinnerware is fired in cylindrical cases called --(?)--.

23. The temperature of the first firing of dinnerware is about --(?)--.

24. The firing of dinnerware removes the water which is held physically and also that which is held in --(?)-- combination.

25. A material, applied after the first firing, made of feldspar, flint, lead oxide, and water is called --(?)--. This material, when fired on dinnerware, produces a --(?)--.

26. There are usually --(?)-- grades of dinnerware.

27. Fine glassware for table use contains --(?)-- and --(?)-- instead of sodium and calcium compounds.

28. Glass can be etched by applying --(?)-- acid.

29. Mirrors are made by causing silver compounds to be --(?)-- to metallic silver upon glass.

REFERENCES FOR FURTHER READING

BEERY, PAULINE G. *Chemistry Applied to Home and Community.* J. B. Lippincott Company, Philadelphia, 1926.

BRINDZE, RUTH. *How to Spend Money.* The Vanguard Press, New York, 1935.

FABRE, JEAN HENRI. *The Secret of Everyday Things.* D. Appleton-Century Company, Inc., New York, 1923.

HODGMANS, CHARLES D., and LANGE, NORBERT A. *Handbook of Chemistry and Physics.* Chemical Rubber Publishing Co., Cleveland, Ohio, 1941. Contains formulas for silvering mirrors.

KING, MARTHA B. *Dinnerware*, pamphlet, Better Buymanship Series, Household Finance Corporation, Chicago, 1936.

MATTHEWS, MARY LOCKWOOD. *The House and Its Care.* Little, Brown and Company, Boston, 1937.

NAYLOR, NELLIE M., and LE VESCONTE, AMY. *Introductory Chemistry with Household Applications.* D. Appleton-Century Company, Inc., New York, 1933.

REICH, EDWARD, and SIEGLER, CARLTON JOHN. *Consumer Goods.* American Book Company, New York, 1937.

RUSH, CHARLES E., and WINSLOW, AMY. *Modern Aladdins and Their Magic.* Little, Brown and Company, Boston, 1927.

UNIT 23

The Chemistry of Fuels and Heating

Ancient man lived in caves, ate raw meat and other uncooked foods, and wore animal skins for warmth. He did not know how to use fire. In fact, the earliest people lived but little better than animals.

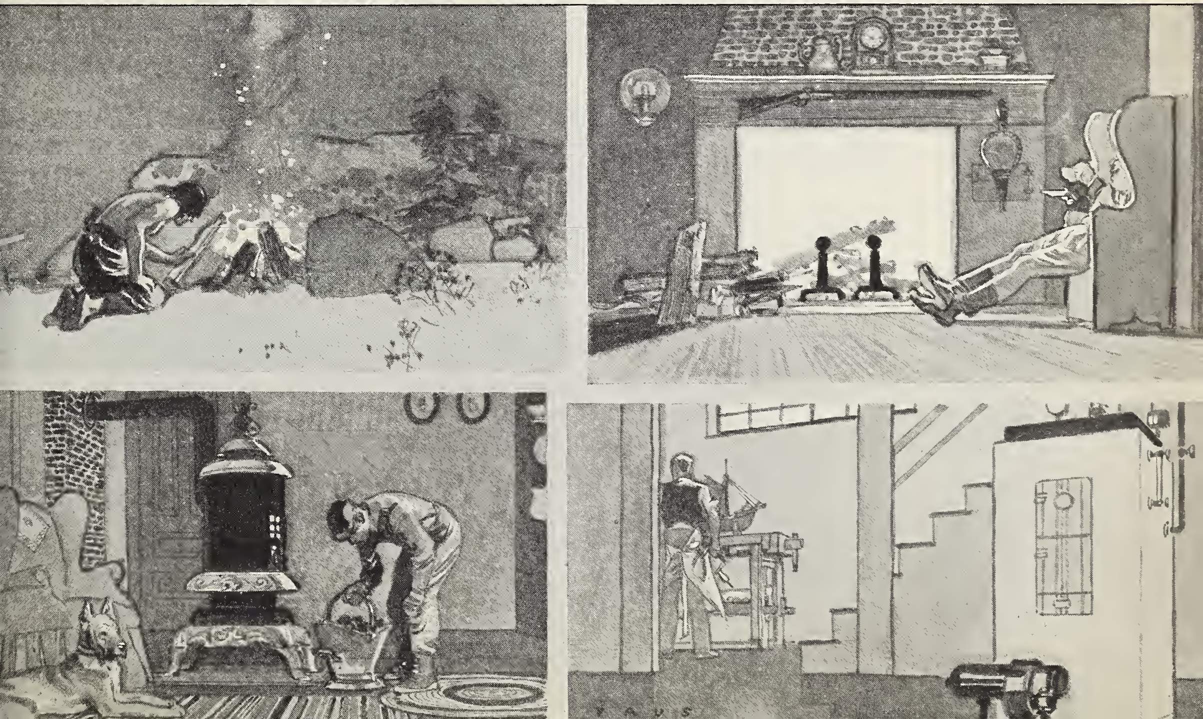
The time and place of the discovery of the usefulness of fire are not known, but with this discovery began man's rise to a higher standard of living. Fire has made it possible for man to live comfortably, to change his style of dress, and to prepare his food so that it is more enjoyable to eat. Fire has made industries possible which, in turn, produce articles that make life more livable and enjoyable. In fact, the knowledge of fire and how to use it effectively has closely accompanied the rise of civilization.

The effect of fire upon the development of civilization would have been much less if man had not learned many new ways to produce fire and new methods of making it useful. The discovery of such fuels as coal, oil, and gas has meant much in the improvement of heating. New appliances which make fire adaptable to any situation have been developed for all fuels. The open fireplace limited the use of fire. The invention of stoves, furnaces, and boilers has made it possible for fire to be used for many different purposes. Future discoveries undoubtedly will result in new uses of benefit to mankind.

PURPOSES TO BE ACHIEVED

1. To discover the fuels which are best for heating the home.
2. To understand how fuel produces heat.
3. To learn ways of selecting the most economical fuel.
4. To learn how to select intelligently the best fuel and the most efficient heating system for the home.
5. To realize the part that man has played in making natural and artificial fuels available for heating purposes.

The development of methods of heating. What part has chemistry played in these changes?



PROBLEMS TO BE SOLVED

1. What fuels are used in the home?
2. How does fuel produce heat?
3. How can the consumer select the most efficient and economical fuel for his home?

Problem 1. What fuels are used in the home?

Kinds of fuel. The most common fuels used in the home today are the solid fuels wood and coal; the liquid fuels gasoline, kerosene, and furnace oil; and the gaseous fuels natural and artificial gas. The use of electricity as a source of heat is increasing.

Solid fuels. Wood. A century ago wood was the only fuel used for home-heating. Although many new fuels have been discovered, wood is still one of the principal fuels of the rural communities. In modern cities its use is almost entirely limited to the fireplace and to kindling a fire. The use of wood for fuel is gradually diminishing, and it is highly improbable that it will ever regain its place as the principal fuel, because the supply is being exhausted.

Wood is essentially cellulose $(C_6H_{10}O_5)_x$. It also contains moisture, inorganic salts, which have come from the water of the soil, and resinous substances, such as turpentine.

The heating value of wood depends on the kind of wood, the percentage of moisture that it contains, and the amount of resinous gums present. Soft woods, such as fir and soft pine, produce little more heat (weight for weight) than hard woods, such as oak and hickory. Newly cut green wood which contains from 30 per cent to 50 per cent moisture may have as much as 40 per cent less heat value than an equal weight of wood which has been air-dried for from eight to ten months. Wood containing a high percentage of resinous substances will produce more heat (weight for weight) than wood containing a low percentage of these substances. Therefore "pitchy" wood is preferable to wood which is low in resinous materials. A pound of dry wood, on burning, will produce from 7800 to 9200 Btu[1] of heat.

The destructive distillation of wood. When wood is heated with an insufficient supply of air, organic materials are driven off as gases, and the cellulose is decomposed to almost pure carbon, called charcoal. The gases may be condensed and distilled. Acetic acid, turpentine, rosin, and wood alcohol, or methanol, may be obtained from these distillates. The charcoal is used for heating and produces hot coals with no smoke.

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[1] Btu is the abbreviation for British thermal unit—the amount of heat necessary to raise the temperature of 1 pound of water 1° F.

Vegetation and animal life which existed during the Carboniferous period. How was coal formed from this abundant growth of plant life?

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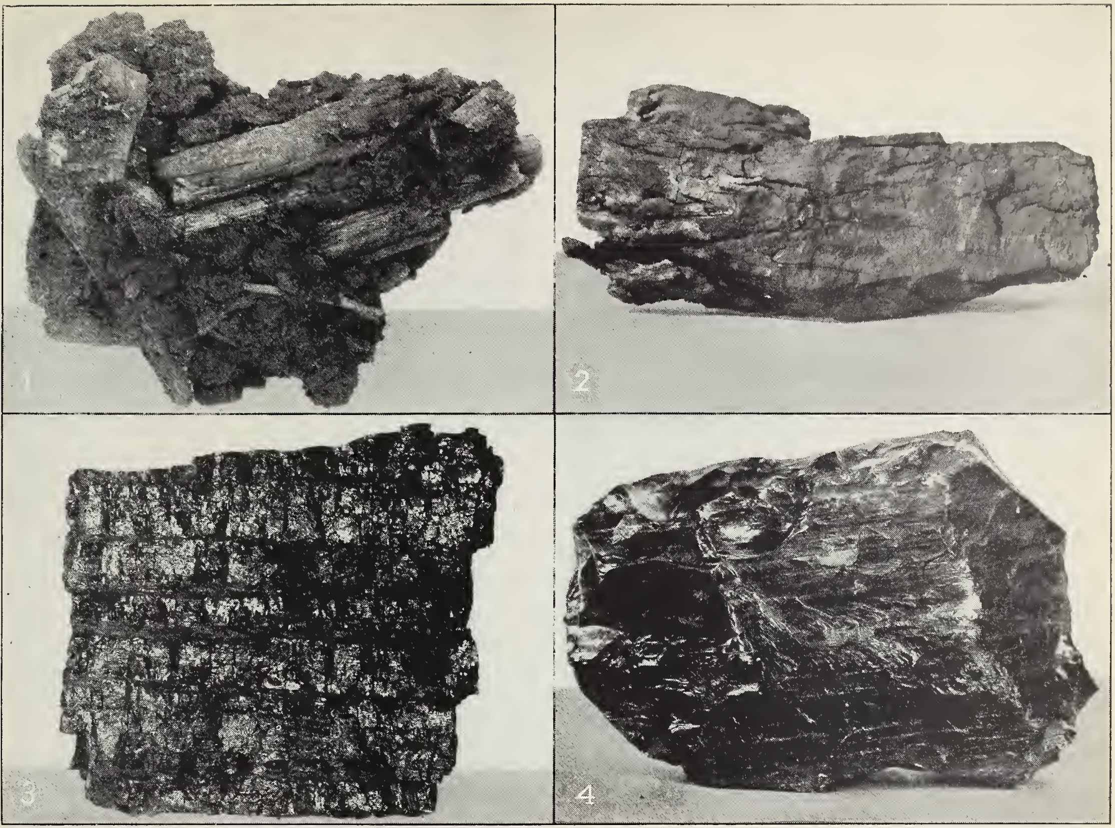


United States Bureau of Mines

Notice in these pictures how time and pressure have brought about increasing carbonization and hardness. The nature of the original material from which the fuel came becomes less and less identifiable as it passes through successive stages of development. The four types of natural fuel shown in this picture are (1) peat, (2) lignite, (3) bituminous coal, and (4) anthracite

Coal. The exact origin of coal is not known. The commonly accepted theory is that millions of years ago, certain parts of the earth were covered with swamps containing dense vegetation. As the vegetation died, it became submerged in water and was gradually covered with earth carried there by rivers, glaciers, and wind. Since the air was excluded, oxidation and decay did not take place. The moist plant materials were then subjected to continuous heat and pressure, which, after millions of years, changed them to coal. The principal component of soft coal is carbon; but when soft coal is subjected to destructive distillation, many complex gaseous and tarry materials are given off.

The kinds of coal. The kind of coal which we find in the earth depends on three factors, namely, the amount of pressure, the amount of heat, and the length of time that it was subjected to these conditions. In those areas where the vegetation was subjected to the greatest amount of pressure and heat for the longest period of time, anthracite, the hardest coal, was formed. When there were less heat and pressure, a softer coal, with more volatile material and less pure carbon, was formed. Such coal is known as bituminous coal.

Another still softer type of soft coal, known as lignite, is found. It usually has a brownish color, which indicates that less complete carbonization has taken place. This is probably due to its more recent origin, less pressure, and less heat.

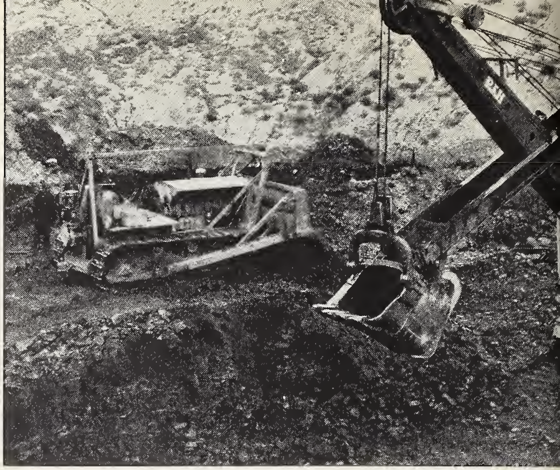
Another interesting fuel in swampy regions is known as peat. It is sometimes called a kind of coal, although it is more nearly a woody material. It is formed in bogs where vegetation grows upon the dead layers of previous plant life. The fallen plants are covered by mud and water, which prevent decay and oxidation, and accumulate to a depth of several inches. This fibrous, woody peat, when dried, becomes a fuel ranking between wood and coal.

The mining of coal. Lignite and peat are generally found much closer to the surface of the earth than bituminous coal and anthracite. When close to the surface, coal may be mined by the use of steam shovels. The top layer of earth is stripped off and the coal exposed; it can then be removed by pick and shovel. Most coal is found far enough below the surface so that a shaft has to be sunk to the "vein" and the coal removed by driving a network of passageways, or entries, into the vein.

Coal resources at the present time are estimated at seven trillion tons. Fortunately, a large percentage of this is located in America. With the rapid changes taking place in the use of fuel, there is little danger that this supply will be depleted soon.

The use of coal as a fuel. Coal may be considered one of the new fuels. It came into use as a commercial fuel between 1825 and 1850. Today coal is the most widely used fuel for heating the home. This is because it is found in many localities and is the cheapest fuel in many regions.

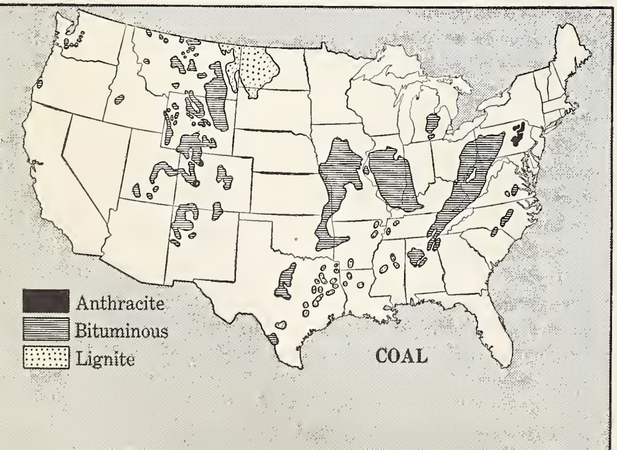
The heat produced by coal depends on the moisture present and the quality of the coal. The more moisture present, the less the heat that the coal will produce. Different lots of the same type of coal may vary considerably in quality. Anthracite, which is about 90 per cent carbon, will yield from 12,000 to 14,000 Btu of heat per pound. Bituminous coal will yield from 12,000 to 13,850 Btu per pound, and lignite from 7000 to 10,500 Btu per pound.



Caterpillar Tractor Company

Eighty tons of coal per hour can be removed in this strip mine by using modern mechanical equipment. The quality of strip coal is generally inferior to that of coal found far under the surface of the earth. Why?

The map shows the locations of important coal deposits in the United States and the different kinds of coal that are to be found



By-products of coal. When bituminous coal is heated in an oven from which air has been excluded, vapors are given off, and the residue is called coke. This product, which is almost pure carbon, produces an intensity of heat equal to that of anthracite and gives off no smoke in burning. It is used extensively in the reduction of iron ores.

The tarry vapors given off in the manufacture of coke were formerly thought to be valueless and were allowed to go to waste. It has been discovered that this waste material contains thousands of useful products.

Liquid fuels. The most commonly used liquid fuels, kerosene, gasoline, and furnace, or fuel, oil, are obtained from petroleum by fractional distillation. There are many theories about the origin of petroleum. One is that an interaction between simple hydrogen compounds, such as water and inorganic carbon compounds, resulted in the formation of petroleum. The more widely accepted theory is that oil was produced by the slow decomposition of marine plant and animal matter which had been previously covered by silt and soil.

The use of furnace, or fuel, oil. The improvements made in oil-burners during the past few years have brought this type of fuel into wider use. There are many grades of fuel oil produced for these burners, but most of them can be classed as light distillates with a slightly higher density and boiling point than kerosene. The heating value of fuel oil will seldom fall below 18,000 Btu per pound.

Kerosene and gasoline. These two types of fuels are both distillates of petroleum. They are used to some extent in small stoves for home-heating but are more commonly used in cooking stoves.

Gaseous fuels. The use of gas as a fuel was first demonstrated by Murdock, an English engineer, in 1802. Since that time, gas has been produced and distributed on a large scale. It is not uncommon for one company to distribute gas to a city or to a region in which there are many cities.

The first gas used for heating purposes was manufactured. Although much is still manufactured, natural gas is being used more and more. In drilling for oil, very often an underground gas pocket is opened which will supply large quantities of natural gas. Pipe lines of several hundred miles have been laid to distribute this gas to cities all over the United States.

Natural gas. The composition of natural gas varies with the locality from which it is obtained.

Mining bituminous coal in an underground mine near Price, Utah

Caterpillar Tractor Company

Skelly Oil Co.

Bottled gas brings to the houseowner who lives beyond the city gas mains the same convenience in gas fuel that the city dweller enjoys

The chief constituent of natural gas is methane (CH_4), which, in most cases, is present in the gas to the extent of 85 per cent to 95 per cent. Natural gas, if properly mixed with air, burns with a blue, nonluminous flame.

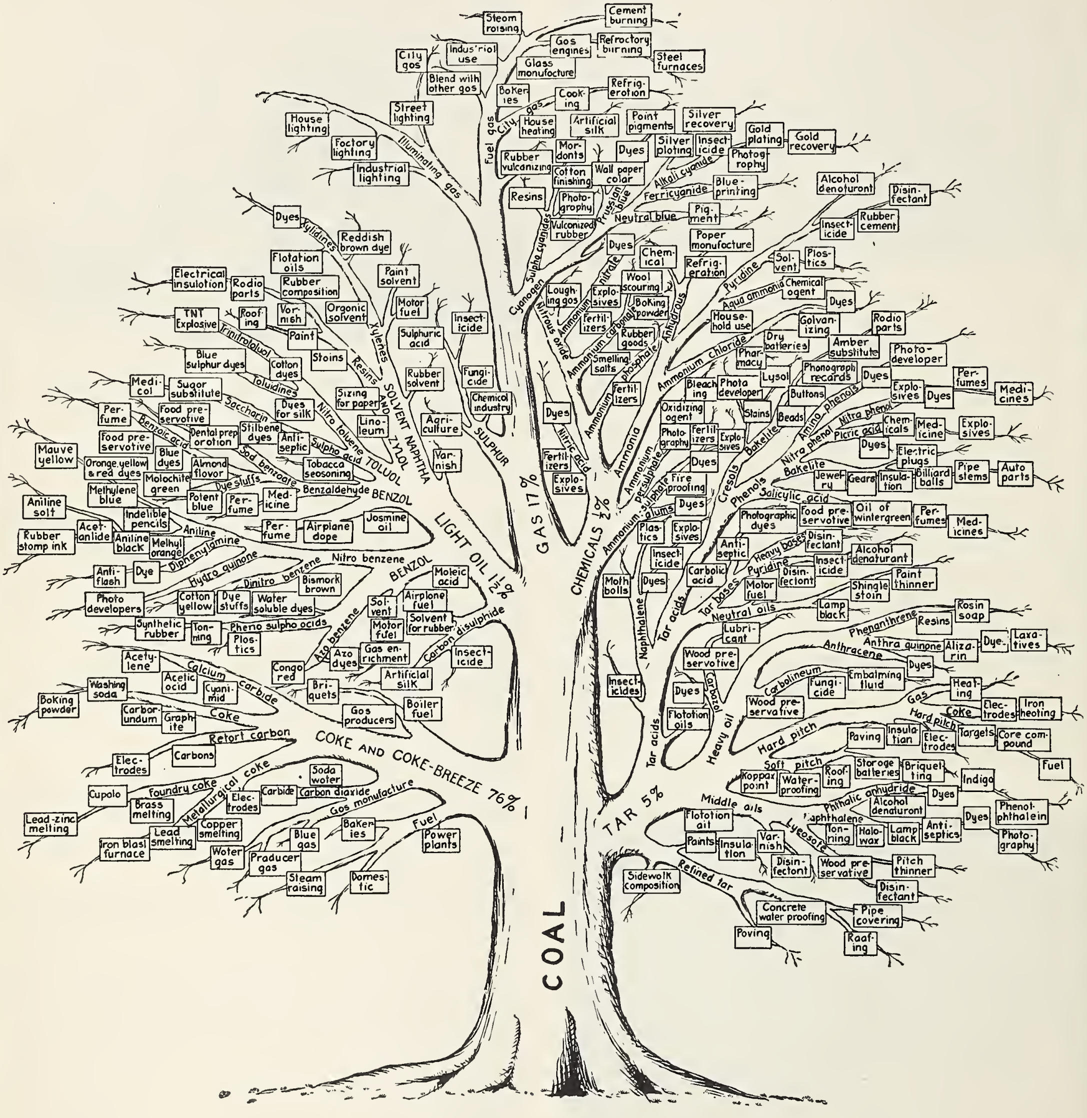
Although natural gas was first used about one hundred years ago, it did not become very important as a fuel until 1890. In recent years its use has increased greatly.

Natural gas is used as a fuel for heating, in stoves and furnaces, and also for cooking. It produces a very hot flame and supplies from 800 to 1100 Btu per cubic foot of gas.

In recent years "bottled" gas has been distributed in areas where piped gas is not available. The bottles are attached to gas ranges, and the same kind of heat is obtained as that produced by piped gas. Some of the gas compressed in bottles is obtained from petroleum. This gas is generally propane and does not have as high a heat value as natural gas. Some companies are now selling bottled natural gas.

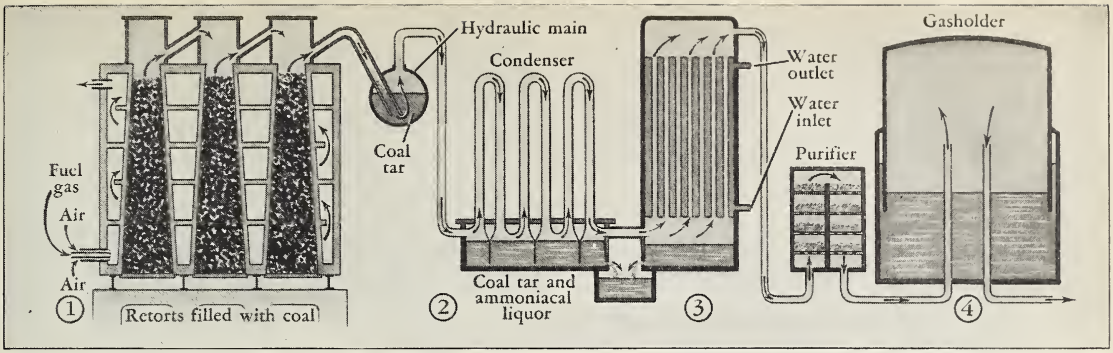
Artificial gas. Manufactured gas is still used to a great extent as a source of heat for the home. The two principal sources of artificial gas for home consumption are coal and water.

Coal gas. This gas is made by the destructive distillation of bituminous coal. The coal is heated



United States Bureau of Mines

A coal-products tree as pictured by the United States Bureau of Mines. How many coal products can you count on this tree? What part has the chemist played in producing these products?



The principal apparatus used in the manufacture of coal gas

in a closed retort, as shown above. As the coal is heated, the gases produced are driven into the hydraulic main, where some of the ammonia and coal tar is condensed and collected. The more volatile gases then pass into the condensers. As cold water circulates over the coils, more of the coal tar and ammonia is condensed. As the gas moves through the purifier, which contains iron compounds, the sulfur impurities, hydrogen sulfide (H_2S) and sulfur dioxide (SO_2), are removed. The purified gas then passes into the gasholder.

A ton of good bituminous coal produces about 380 pounds (10,000 cubic feet) of coal gas, 120 pounds of coal tar, 100 pounds of ammonia, and 1400 pounds of coke.

Coal gas consists of approximately 40 per cent hydrogen, 40 per cent methane, and 10 per cent carbon monoxide. It is the most widely used artificial gas for heating purposes. One cubic foot of the gas, when burned, will supply from 450 to 500 Btu. Coal gas has an odor which makes it easy to detect.

Water gas. This gas is made by passing steam over hot, incandescent coke or hard coal. The coke is heated to a temperature of 1000° C by passing hot air over it. The air is then shut off, and steam is passed over the hot coke. The temperature soon drops, the steam is shut off, and hot air is passed over the coke again. In the reaction the carbon of the coke combines with the oxygen of the water to produce carbon monoxide and hydrogen. This mixture is known as water gas.

$$H_2O + C \xrightarrow{\text{water gas}} CO + H_2$$

Water gas produces from 250 to 350 Btu per cubic foot. Coal gas is frequently mixed with water gas to secure a greater production of heat and to give the water gas an odor. Pure water gas has no odor and may be dangerous, because if an appliance should develop a leak, the gas could not be detected.

Electricity. Although electricity cannot, in the true sense of the word, be classed as a fuel, it is sometimes used for heating purposes in the home. All the fuels that have been discussed are from limited natural resources. There is a possibility that these resources may become depleted. Electrical energy is frequently produced by the use of these fuels but may also be manufactured by water power, which will not be depleted. In fact, much of our water power is not being used.

The modern electric stove is economical to use in communities where the cost of electric power is reasonable

General Electric Co.

The cost of electricity in most regions of the United States is still too high for it to be used widely as a fuel. In many localities, however, the use of electric ranges is increasing rapidly. As time passes, we may expect that electricity will become cheaper and that it will not be uncommon for homes to be heated with it.

EXERCISES

1. How is the use of fire related to the development of civilization?
2. Why should you study the chemistry of fuels?
3. What is a fuel?
4. What are the common fuels used in heating the home?
5. Describe the different kinds of coal.
6. Describe the process of destructive distillation.
7. Define the British thermal unit.
8. How long has coal been used as a fuel?
9. How is coke produced?
10. What is the difference between coke and charcoal?
11. How does destructive distillation differ from fractional distillation?
12. What is the composition of natural gas?
13. How is coal gas manufactured?
14. How does coal gas differ from water gas?
15. Why is electricity not usually considered a fuel?

Problem 2. How does fuel produce heat?

Complete combustion of fuels. When a substance unites with the oxygen of the air to produce heat in quantities that can be used for heating, it is called a fuel. All the fuels which have been discussed have potential chemical energy. When oxygen is made to unite rapidly with these fuels, the stored-up chemical energy is transformed into heat energy, which is liberated and used.

The following equations will illustrate the burning of three fuels when sufficient oxygen is present to bring about complete combustion:

1. *Coal.* The chief constituent is carbon.

$$C + O_2 \longrightarrow CO_2\uparrow + \text{heat energy}$$

2. *Natural gas*

$$CH_4 + O_2 \longrightarrow CO_2 + 2\,H_2O\uparrow + \text{heat energy}$$

3. *Water gas*

$$2\,CO + O_2 \longrightarrow 2\,CO_2\uparrow + \text{heat energy}$$
$$2\,H_2 + O_2 \longrightarrow 2\,H_2O\uparrow + \text{heat energy}$$

Incomplete combustion. Fuels may be completely utilized if the proper amount of oxygen is fed to the fire. Frequently, owing to the lack of proper adjustment, an insufficient amount of air is used, and incomplete combustion of the fuel results.

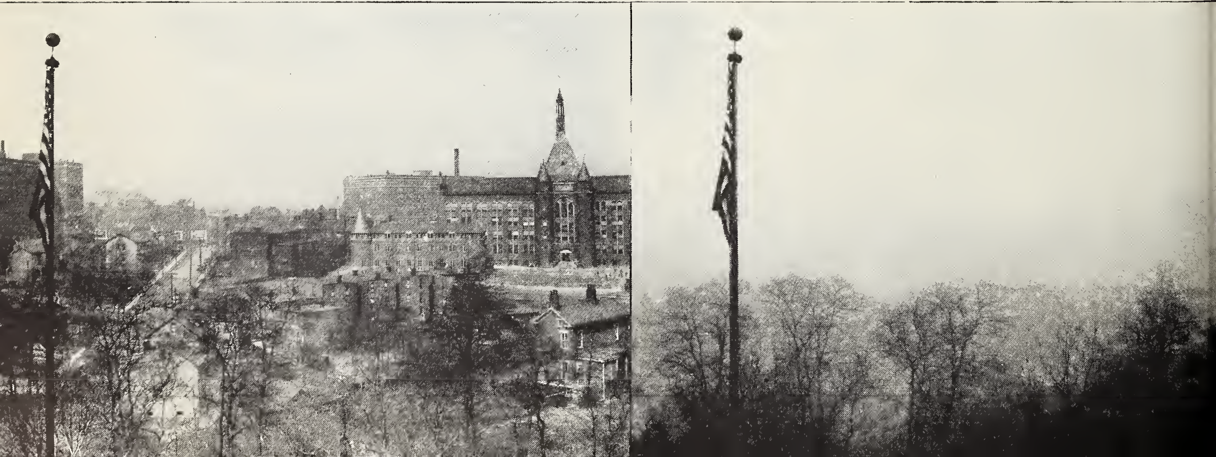
When incomplete combustion occurs, the carbon of the fuel usually forms the dangerous poisonous gas carbon monoxide:

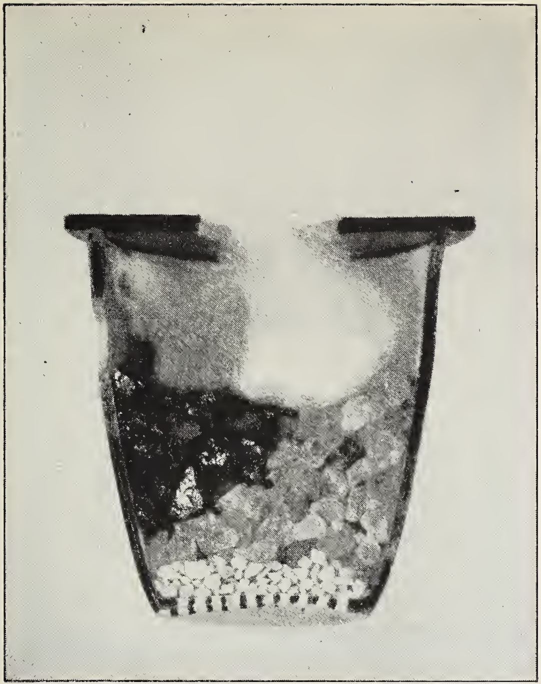
$$4\,C + 2\,O_2 \longrightarrow 2\,CO\uparrow + CO_2\uparrow + C$$

Incomplete combustion is always accompanied by the escape of carbon in the form of soot. A chimney which is belching forth clouds of black smoke is a positive indication that the fuel is not being completely oxidized and that carbon monoxide and free carbon are being formed.

Two pictures of the business district of a city taken from the same location. The unpleasant, smoky condition of the atmosphere shown in one picture is caused by the condensation of water around small smoke particles. This smoky condition is called "smog." What are the hazards of a smoky atmosphere? How may the smoke nuisance be controlled?

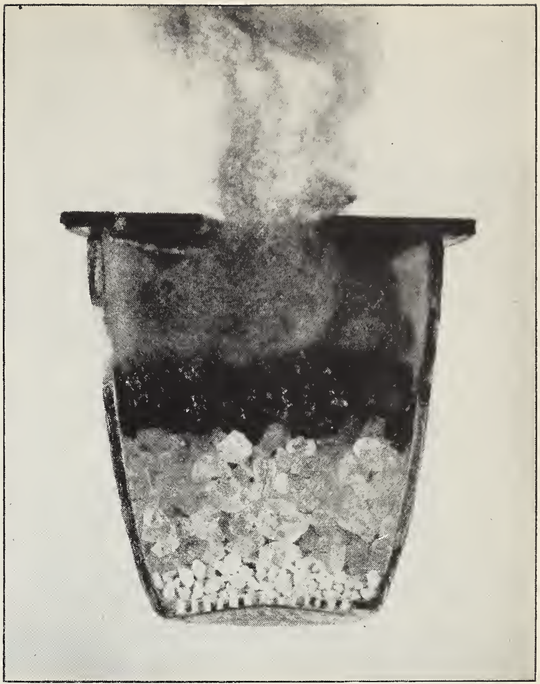
United States Bureau of Mines





United States Bureau of Mines

The proper method of firing a furnace with coal. Notice that all the gases produced by the heated coal are burning



United States Bureau of Mines

The wrong way of adding coal to a fire. Notice the smoke which results from the incomplete combustion of the escaping gases

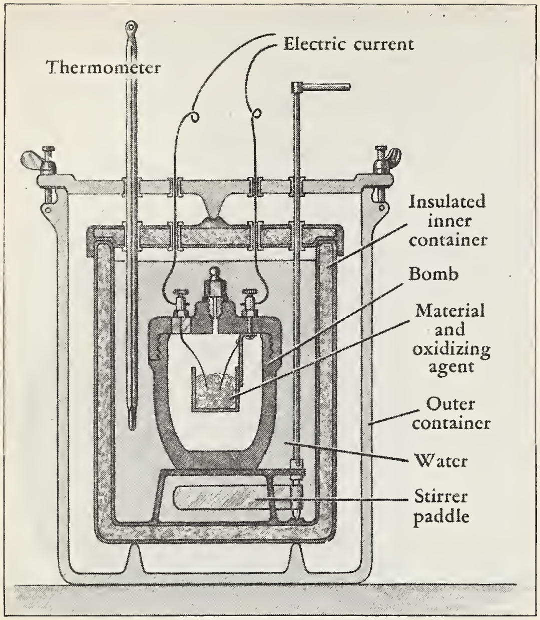
The improper firing of a coal furnace or stove has several disadvantages. In the first place, it is expensive. If smoke or soot is produced in burning, the full heat value of the coal is not being obtained. Some people lose as much as 50 per cent to 60 per cent of the heat value of fuel because they do not fire their furnaces properly. Secondly, the smoke nuisance in cities, which is becoming a major problem, is largely due to the improper firing of furnaces. It is definitely known that smoke is affecting the health of people in certain urban centers, that it is marring the beauty of cities, that it is creating much dirt, and that it is causing expenses in homes because of frequent redecoration and laundering.

There is always a great danger in the home when gas or oil appliances are not properly regulated. A gas stove or grate whose jets are not adjusted to admit the proper amount of oxygen is a potential producer of the lethal gas carbon monoxide. Many persons have been overcome by this gas without being aware of its presence, and have been killed.

Efficiency in fuels. To obtain the most value from the burning of gas, the appliances must be regulated frequently. If the air-regulators are opened sufficiently so that the flame does not have a yellow tip, the gas is completely burned and utilized.

The greatest loss in efficiency comes from coal stoves and furnaces that are improperly fired. This loss can be eliminated by learning how to fire a stove or furnace. By so doing, money can be saved, and the smoke nuisance in the community can be abated.

How to build a fire. Have you ever observed, during the early morning, chimneys belching forth large volumes of black smoke? Much of this pollution of the atmosphere is due to new fires that are being built. If the fires which are producing this smoke had been started by the "upside-down method," little smoke would have been produced. In this method all the ashes are removed from the grate and ashpan. From two to three inches of small coals are placed on the grate. On top of the coal is placed paper and then plenty of kindling.



An apparatus called a bomb calorimeter is used to determine the heat value of a fuel. The material to be burned is carefully weighed and mixed with a definite amount of a powerful oxidizing agent and placed in the bomb. The bomb is surrounded by a known volume of water. When the mixture in the bomb is ignited by an electric spark, the heat evolved is absorbed by the surrounding water. The increase in the temperature of the water is shown by a sensitive thermometer. From the increase in temperature of the surrounding water, the heat value of the fuel may be determined

The paper is then ignited, and the wood begins to burn. The burning wood heats the coal to its kindling temperature, causing the top layer to vaporize.

These vapors must pass through the zone of burning and are, therefore, completely burned. If the fire is started in the usual way, by placing the kindling below the coal, the vapors of the burning coal do not pass through a burning area. The result is that these vapors pass into the chimney and are expelled as dense smoke.

Firing with coal. If a few simple rules are followed in firing a furnace or stove with coal, the fuel bill can be greatly reduced, and smoke can be practically eliminated. In the morning the grate should be shaken gently to remove the powdery ash, but some ash should be left on the grate. Clinkers should be removed. The fire bed should never be allowed to become too thin, and the fire should not be disturbed by poking it. Always leave at least half the live coals uncovered so that the flames can completely burn up the gases that come off the new coal. If you completely cover the fire with new coal, you smother it, and the gases, instead of burning, pass out of the chimney as smoke and soot. Also, gases may be entrapped so that a puffing explosion occurs when they unite.

To escape these difficulties, you can gently push the live, flaming coals to the back, as shown in the picture at the left on page 367. Then drop the new coal over the lip of the fire door and fill the vacated space to the level of the door. Variations of this method may be used. The fire is not smothered when this method is used. The live coals heat the new coal, and, as the vapors are driven off, they are completely burned.

For a quick fire, open the lower, or ashpit, draft door, leaving it open for from ten to thirty minutes after firing, and close the check draft in the smoke pipe. For a slower fire, open the ashpit draft door slightly and leave it that way. If a heating plant does not respond to these procedures, it should be checked by a heating engineer.

EXERCISES

1. When fuels are burned, what are the products?

2. What is the difference between complete and incomplete combustion?

3. How can you tell that a fuel is burning incompletely?

4. Why is the production of smoke when a fuel is burned an indication of inefficiency?

5. What is the correct method of building a fire?

6. How may smoke be eliminated when a fuel is burned?

Problem 3. How can the consumer select the most efficient and economical fuel for his home?

How to buy coal. Although coal is still the most widely purchased fuel, most people do not know how to select it scientifically. When you purchase coal, you are really purchasing heat, and, as has already been explained, there is considerable variation in the heat value of coal.

The factors to be considered in buying coal are

1. The kind and size of coal to which the heating system is adapted.
2. The British-thermal-unit value per pound.
3. The per cent of fixed carbon.
4. The per cent of volatile matter.
5. The per cent of moisture.
6. The per cent and nature of the ash.

Two kinds of coal may both have a British-thermal-unit value of 12,500 per pound and yet not produce the same amount of heat in a furnace or stove. The heat value of coal is due to the fixed carbon, which is almost completely converted into heat, and the volatile matter, one half of which is utilized in producing heat. The British-thermal-unit value of a particular kind or lot of coal is found by completely burning the fixed carbon and the volatile matter in a bomb calorimeter. This calorimeter is similar to the one shown and described on page 368. However, in a furnace or stove much of the volatile matter escapes in the smoke and does not produce heat.

The formula for determining the useful heat value per dollar's worth of coal is as follows:

$$\frac{\text{Btu} \times 2000 \text{ pounds}}{\text{Cost per ton of coal in dollars}} = \text{Useful Btu per dollar's worth of coal}$$

To illustrate the use of this formula, let us compare the heat value of two kinds of semibituminous coal.

	Coal A	Coal B
Btu per pound	11,600	10,130
Ash	7.3 per cent	3.9 per cent
Moisture	9.2 per cent	19.6 per cent
Price per ton	$7.25	$7.25

If these values are now placed in the formula, the British thermal units per dollar may be obtained for each coal.

Coal A

$$\frac{11{,}600 \times 2000}{7.25} = 3{,}200{,}000 \text{ Btu per dollar}$$

Coal B

$$\frac{10{,}130 \times 2000}{7.25} = 2{,}794{,}000 \text{ Btu per dollar}$$

Coal A appears to be a better buy than *Coal B* because it yields about 14 per cent more British thermal units per dollar. Another factor, however, which needs to be carefully considered is the ash. *Coal A* will produce almost twice as much ash as *Coal B*. To some this extra amount of ash may not be objectionable, but others may wish to purchase *Coal B* at a slightly higher figure and have less ash to contend with.

Anyone can use this scientific method of selecting coal. The analysis of any coal sold in your community can usually be obtained from the coal dealer. If not, it can be obtained from the state bureau of mines or the United States Bureau of Mines.

There are two other factors to be taken into consideration in purchasing coal. One of these is its moisture content. A coal dealer who buys his coal at the mine when it is dry may make many additional dollars when he sells it if it has been moistened by rain or snow. This moisture adds many pounds of weight, which, however, does not increase the heat value of the coal. The other factor is that of the dust produced by the coal. To aid in home cleanliness, you should insist that coal be treated with a spray of oil so that the dust will not fly when the coal is being placed in the storage bin.

Relative cost of coal, oil, and gas. The price of coal, oil, and gas varies considerably in different parts of the United States. In most regions coal is the cheapest fuel when the actual expenditure for fuel alone is considered.

In the following table the average British-thermal-unit value is given for the four most commonly purchased fuels:

Bituminous coal	12,000 Btu per pound	$9.60 per ton
Fuel oil	18,000 Btu per pound	.05 per gallon
Natural gas	900 Btu per cubic foot	.35 per 1000 cubic feet
Artificial gas	500 Btu per cubic foot	.19 per 1000 cubic feet

This table shows that when coal has a British-thermal-unit value of 12,000 per pound and sells at $9.60 per ton, it is equal in value to fuel oil having 18,000 Btu per pound and selling at 5 cents per gallon. To yield the same number of British thermal units per dollar, natural gas with a heat value of 900 Btu per cubic foot would have to sell at 35 cents per 1000 cubic feet, and artificial gas with a heat value of 500 Btu per cubic foot would have to sell at 19 cents per 1000 cubic feet.

EXERCISES

1. What does one need to know in order to buy coal intelligently?
2. What is a bomb calorimeter?

Comparison of Hot-Air, Hot-Water, and Steam Heating Plants for Small Residences

	Hot Air	Hot Water	Steam
Cost of installation	Least expensive, except forced air, which is most expensive of all	Most expensive	One-pipe system less expensive than hot water. Two-pipe system same as hot water
Cost of operation	Lowest	Medium	Highest
Quickness of response to firing	Most responsive	Least responsive	Medium response
Evenness of heat	Least even	Most even; maintains heat longest	Medium evenness
Cleanliness and odor	Some impurities in air unless filtered; some odor	Cleanest; no odor	Clean; odor of steam
Moisture in air	Air dry, even if humidified	Satisfactory	Satisfactory
Ventilation and circulation of air	Best	Average	Average

3. Obtain the analysis and price of two different kinds of coal and determine by means of the formula on page 369 which coal is more economical to buy.

4. How many cubic feet of natural gas would have to be burned to yield the same number of British thermal units as could be obtained from a pound of bituminous coal? (Use the table on page 369.)

5. What is the cheapest fuel sold in your community?

6. What are the relative costs of fuels sold in your community in terms of the actual British thermal units received?

7. Considering the various factors involved, which type of heating system do you consider best for small homes?

PROBLEMS FOR FURTHER STUDY

1. How is coal analyzed?

2. What is the British-thermal-unit rating per dollar of the various brands of coal sold in your community?

3. What are the different types of briquettes? How are they made?

4. How are fireplace logs treated so that they will burn with beautifully colored flames?

5. Write a description of the plant and animal life of the Carboniferous period.

6. What are the products of the destructive distillation of wood?

7. How is acetylene made? How is it used as a fuel?

8. What are the costs of installation of the heating systems sold in your community?

9. How long will the fuel supply in the United States last? What is being done to conserve it?

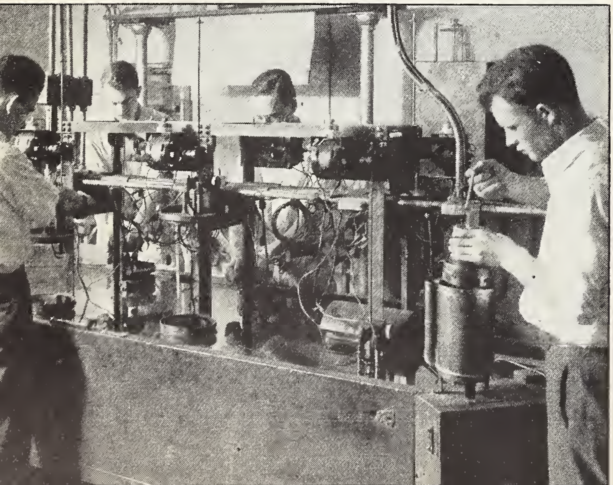
10. What are all the sources of danger from carbon monoxide? How are persons who are overcome by this gas treated?

11. How are matches made?

12. What are the kinds of heating systems used in the home? How does each work?

These scientists are determining the calorific value of several samples of coal in the laboratory of the Bureau of Mines. This apparatus is known as a multiple-unit calorimeter

United States Bureau of Mines



UNIT EXERCISES

Some of the statements which follow are true, and some are false. On a separate sheet of paper write the word *true* for those which are true and the word *false* for those which are false. Do nothing for those about which you are doubtful. Rewrite the false statements so that they are true.

1. Fire was discovered by Priestley.

2. Coal was first used as a fuel about two hundred years ago.

3. Coal is a liquid fuel.

4. Wood is composed chiefly of $(C_6H_{10}O_5)_x$.

5. A pound of dry wood, on burning, will produce about 14,000 Btu.

6. Hard woods produce more heat, weight for weight, than soft woods.

7. The origin of coal is definitely known.

8. Bituminous coal is known as hard coal.

9. Coal is considered to have been formed by the slow oxidation of plant materials.

10. Lignite and peat are usually found closer to the surface of the earth than bituminous coal.

11. Anthracite is known as hard coal.

12. Coal contains volatile hydrocarbons.

13. Coal tar is a by-product of the making of coke.

14. Bituminous coal will yield, when burned, from 1200 to 1300 Btu per pound.

15. Coke is almost pure carbon.

16. CH_4 (methane) is the principal constituent of natural gas.

17. Coal gas is produced by the destructive distillation of coal.

18. Coal gas contains hydrogen.

19. Water gas is made by passing alternate currents of hot air and steam over coke.

20. Water gas contains carbon monoxide.

21. Carbon monoxide is produced when a fuel burns with a sufficient supply of oxygen.

22. $CH_4 + O_2 \longrightarrow CO_2 + 2\,H_2O$ + heat is the equation for the burning of natural gas.

23. A fuel contains potential energy.

24. Incomplete combustion is indicated by the presence of a yellow flame.

25. The presence of smoke in the atmosphere presents a health hazard.

26. Coal may be burned without smoke.

27. The proper way to apply fresh coal to a fire is to pile the coal directly on top of the glowing embers in the firebox.

28. Coal should be purchased according to the British thermal units that it will furnish per dollar.

29. The ash content of coal is an unimportant factor to consider when buying coal.

30. The moisture content of coal affects its heating value.

31. Coal is always the cheapest fuel to buy.

32. Artificial gas produces more British thermal units per cubic foot than natural gas.

33. Coal which yields 12,000 Btu per pound has approximately the same value at $9.60 per ton as natural gas with a rating of 900 Btu per cubic foot at 5 cents per cubic foot.

34. A hot-air furnace is the least expensive heating plant for small residences.

35. A hot-water heating system furnishes the most even heat.

REFERENCES FOR FURTHER READING

Barkley, J. F. *Questions and Answers for the Home Fireman.* United States Department of the Interior, Bureau of Mines, Washington, D. C., 1940.

Hausrath, Alfred, and Harms, John. *Consumer Science.* The Macmillan Company, New York, 1939.

Matthews, Mary Lockwood. *The House and Its Care.* Little, Brown and Company, Boston, 1937.

Mohn, Paul E. *Home Heating*, Better Buymanship Leaflet. Household Finance Corporation, 919 North Michigan Avenue, Chicago.

Osborn, Frederick A. *Physics of the Home.* McGraw-Hill Book Company, Inc., New York, 1935.

Senner, A. H. *The Domestic Oil Burner*, Circular No. 405, United States Department of Agriculture, Washington, D.C., 1930.

Whitman, Roger. *First Aid for the Ailing House.* McGraw-Hill Book Company, Inc., New York, 1934.

UNIT 24

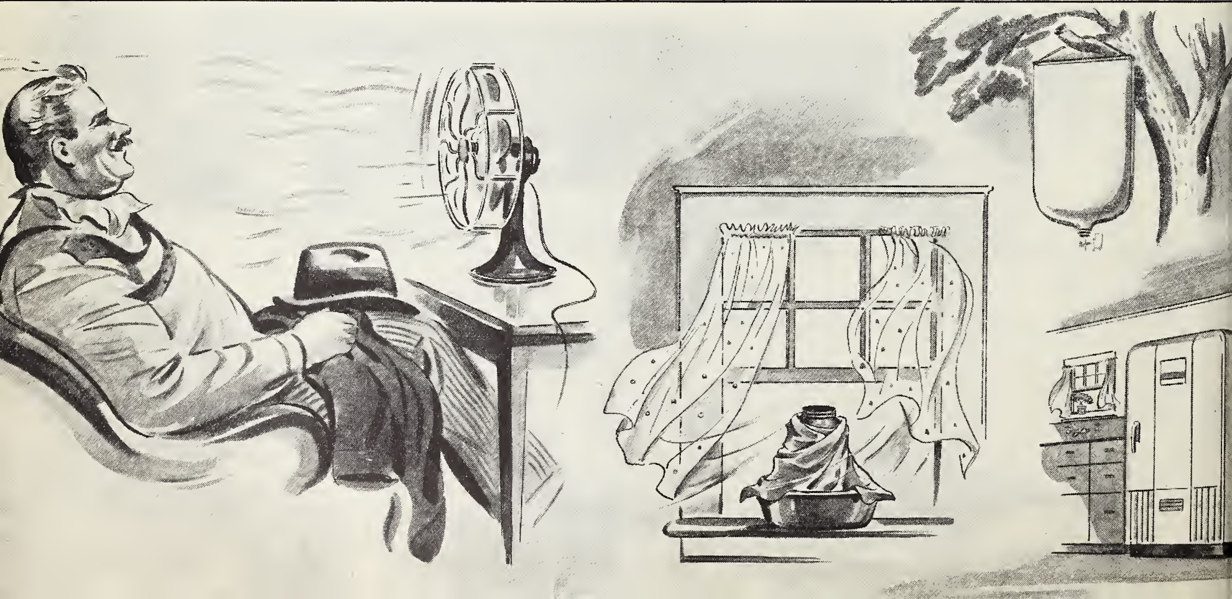
The Chemistry of Refrigeration and Air-Conditioning

The problem of refrigerating food is a very old one. Greek historians explained how the people of ancient times used cooling by evaporation. This practice was followed also by the early civilizations of India, China, and Japan. Emperor Nero had snow brought down from the mountains to cool his beverages. In the seventeenth century the storage of ice and snow in winter so that they could be sold in summer had become a profitable business in Europe. People had learned that food was more palatable and stayed fresh longer when it was kept cold. However, the relationship between refrigerated foods and health was yet to be learned.

Man is constantly attempting to change his environment to suit his needs. One of his first accomplishments was his useful control of fire and heat. Roger Bacon, one of the first scientific experimenters, told how useful it would be if man could have the same control of cold as of heat. The higher forms of animal life have automatic means of cooling themselves based on the principle of the evaporation of water. The most elaborate automatic refrigerator of today is based on this same principle of the evaporation of a liquid. You may demonstrate to yourself the cooling effect of the evaporation of a liquid by pouring a little ether or alcohol on your hand. The cooling effect that one feels upon emerging from a swim in the summertime is another familiar example of how evaporation cools. The knowledge which scientists have obtained about this principle has enabled them to build automatic cooling machines. Consequently, in this modern day, we are able to control cold as well as heat.

Refrigeration and air-cooling have added greatly to our health and comfort. The use of ice and automatic refrigeration in the transportation and storage of foods has made it possible to bring the fresh fruits and vegetables of the southland to the people of the north during the winter months. Moreover, in the home, through either ice or automatic refrigeration, foods may be maintained in the condition in which they first reach the home. We are inclined to accept

These pictures illustrate ways of cooling. Different situations are illustrated, but the scientific principle involved is the same in each. That principle is that the evaporation of a liquid produces a cooling effect. The degree to which a given tempera ture is lowered depends on the rapidity and the duration of the evaporation



these conditions as commonplace. They are very important, however, since they enable us to have an adequate supply of vitamins and minerals in our daily life. The fact that nutritional diseases and "spring fever" have been reduced in the homes and communities which can afford refrigeration is proof that the health of people has been improved by refrigeration. Also, the refrigeration of food has saved the individual consumer hundreds of dollars by lessening the spoilage of perishable foods.

Perhaps we are more conscious of the additional comfort we enjoy from air-cooling because we feel directly this improvement. Cool theaters and stores are direct applications of the scientist's knowledge of refrigeration. We are now beginning to see the science of refrigeration extended to our homes and automobiles, so that it may before long be possible to live in an atmosphere of ideal temperature and humidity, regardless of the outside environment.

PURPOSES TO BE ACHIEVED

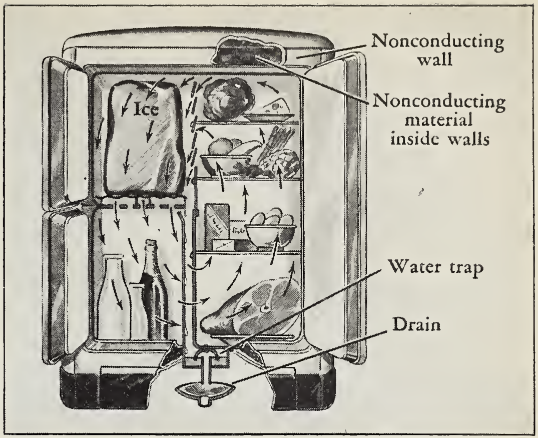
1. To learn the principles of chemistry involved in refrigeration and air-cooling.
2. To discover how refrigeration and air-cooling have improved living.
3. To learn how to buy a refrigerator intelligently.
4. To become familiar with modern developments in air-cooling.

PROBLEMS TO BE SOLVED

1. How does a refrigerator protect food?
2. What types of food refrigeration are used in the home?
3. How does an ice refrigerator work?
4. How does an electric refrigerator work?
5. How does a gas refrigerator work?
6. What are the relative merits of the different kinds of refrigerators used in the home?
7. How may a refrigerator be maintained at maximum efficiency?
8. How may mechanical refrigeration be used in cooling the home?

Problem 1. How does a refrigerator protect food?

Refrigeration retards the growth of germs in food. The most desirable temperature for the food compartment is between 40° and 50° F. This temperature should not vary beyond these two limits if proper food preservation is to be maintained. If the temperature rises above 50° F, germs will immediately begin to reproduce. Once this condition starts, the food can never be brought back to a fresh state, even though it is cooled to the proper temperature again.



Trace the circulation of air in this refrigerator. What causes these air currents?

There are two factors which influence the freshness of food in a refrigerator. They are temperature and humidity. All foods cannot be maintained in the same degree of freshness by the same temperature and the same degree of humidity. There is no one ideal temperature at which all foods should be kept. For example, bananas are best stored at a temperature of 60° F, whereas potatoes will keep best at a temperature between 36° F and 38° F. A lower temperature for either of these foods promotes deterioration. Milk and meat are best stored in the home refrigerator at a temperature between 35° F and 40° F. Again, lettuce, celery, and all leafy vegetables will remain crisp and fresh if the temperature is kept low and a relative humidity above 90 per cent is maintained.

Since too much moisture causes most foods to spoil more rapidly, it is essential that the food compartment of an ice refrigerator be kept dry. Mechanical refrigerators have a tendency to dry food because of the low humidity in the food compartment. To overcome this drying effect, a special

Westinghouse

The modern electric or gas refrigerator provides excellent refrigeration for the preservation of vegetables, meats, and other foods. It adds greatly to our health and high standard of living

closed compartment, called a crisper or humidifier, is provided to keep the fresh leafy vegetables from losing their moisture.

Other changes take place in food besides those due to the growth of germs. They are known as chemical changes and are brought about by the enzymes in the food. An example is the oxidation of fats, which produces rancid substances. The rate at which these chemical changes take place in foods is determined by the degree of coldness maintained in the food compartment. The rate at which food ripens and deteriorates is generally about doubled for each rise in temperature of 18° F.

If we take all these factors into consideration, we may safely say that a temperature range of 40° F to 50° F is the one which should be maintained to secure maximum efficiency in a home refrigerator.

How does a refrigerator cool food? If you desire to know how a refrigerator cools, it is necessary that you understand how heat energy is transferred. Heat energy cannot be destroyed; instead it merely flows from material which is warm to that which is cool. In order that a refrigerator may produce a low temperature, the heat which enters it from the warm air of the room or from the food which is put into it must flow into ice or into the cooling unit. The heat thus absorbed is then removed from the cabinet. For example, in the ice refrigerator the heat causes the ice to melt, and the resultant water is drained from the cabinet.

In every refrigerator there must be opportunity for the interior air to circulate, because the air is the medium which carries the heat from the food to the ice or the cooling unit. Warm air is forced up because it is less dense than cool air. The cool air, being more dense, settles to the bottom and forces the warm air up. As air in the refrigerator is cooled by passing over the ice or around the cooling unit, it becomes more dense and drops to the lower part of the cabinet. Therefore it is evident that the ice or the cooling unit should be near the top of the refrigerator and that ample space should be provided so that rapid circulation of air may take place. More rapid cooling is thus secured. The circulation of air in an ice refrigerator is shown in the diagram on page 373.

EXERCISES

1. What basic principle is involved in all kinds of refrigeration?

2. How do the higher forms of animals cool themselves?

3. Why should you learn about the chemistry of refrigeration?

4. How does the refrigeration of food prevent spoilage?

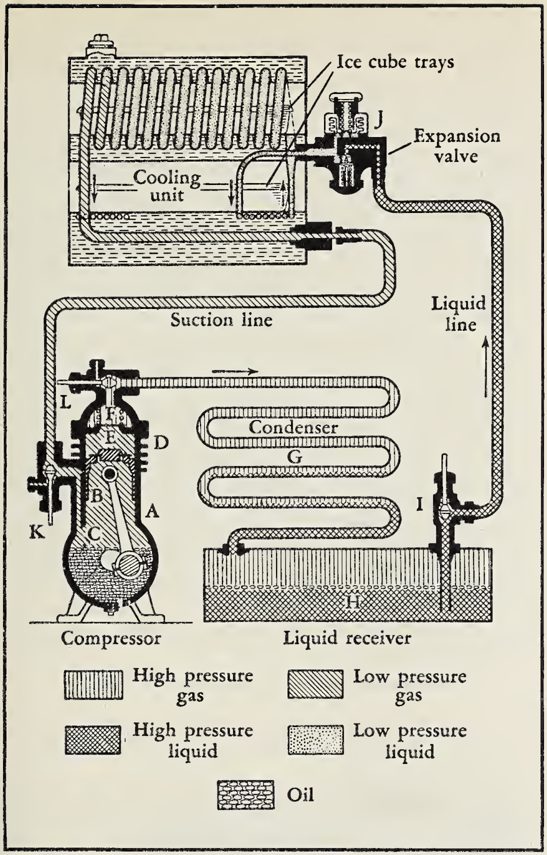
5. Make a list of common foods and the temperatures at which they should be stored to prevent deterioration.

6. What is the best temperature range for the home refrigerator? Why?

7. Why is the proper circulation of air in a refrigerator important?

Problem 2. What types of food refrigeration are used in the home?

Three types of refrigerators. The manufacture of household refrigerators has become one of our giant industries. As this industry has grown, so has our knowledge of the conditions necessary to refriger-



Nash Kelvinator Corporation

The diagram shows the essential processes involved in the operation of an electric refrigerator. Describe these processes as the refrigerant flows through a complete cycle

ate foods adequately in the home. There are now available three types of household refrigerators: (1) those which use ice, (2) those operated by electricity, and (3) those operated by gas or kerosene.

There are other devices for cooling foods, such as homemade cooling boxes, California coolers, and "Dry Ice" chests. All these have value, and information on how to construct them can be obtained from the Department of Agriculture, Washington, D.C.

EXERCISES

1. What types of refrigerators are used in the home? How do they differ?
2. Where may you secure information on making iceless refrigerators?

Problem 3. How does an ice refrigerator work?

Ice absorbs heat. For the most efficient service, the ice in an ice refrigerator should be placed in an upper corner of the box. This arrangement makes possible the maximum circulation of the air in the food compartment.

The cooling effect of ice is due to the absorption of heat when ice changes to water. When a gram of ice at 0° C changes to a gram of water at 0° C, 80 calories of heat energy are absorbed. In a refrigerator this heat is absorbed from the air adjacent to the ice. This air, being cooled, is more dense than the surrounding air and falls to the bottom of the compartment. As it does so, the warmer air and food give up heat to the cool air, causing it to become warmer. It then rises, becomes cool through close contact with the ice, and is recirculated.

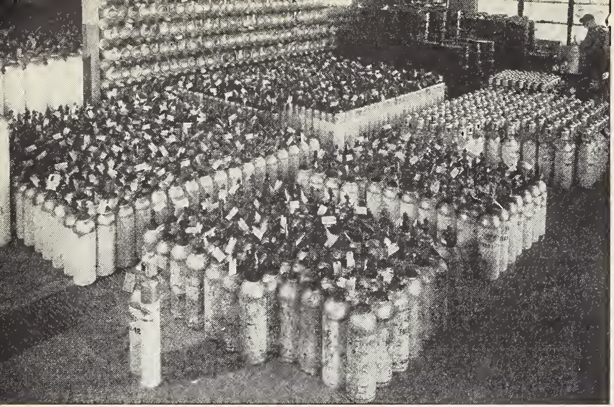
The water which is formed from the melting ice is removed from the ice compartment by a pipe and either is caught in a pan placed under the box or is piped into the sewer system.

EXERCISES

1. How much heat is required to change 1000 grams of ice at 0° C to 1000 grams of water at 0° C?
2. Why should ice be placed in the upper part of an icebox?
3. What becomes of the heat released by warm food which is put in the refrigerator?
4. Explain how an ice refrigerator works.

Problem 4. How does an electric refrigerator work?

Cooling by evaporation. Electric refrigerators are so named because they are operated by an electric current. There are three main parts in the refrigerating unit: (1) an electric motor, (2) a compressor operated by the motor, which compresses the refrigerant, and (3) an evaporator, or cooling unit, in which the compressed liquid becomes a gas. The refrigerant may be any gas which can be easily compressed into the liquid state. Various chemical compounds are used. Among the most common are sulfur dioxide (SO_2), ethyl chloride (C_2H_5Cl), dichlorodifluoromethane (CCl_2F_2), methylene chloride (CH_2Cl_2), and methyl chloride (CH_3Cl). Ammonia (NH_3) is the most widely used refrigerant in commercial refrigeration plants.



E. I. Du Pont de Nemours & Co.

View of shipping house used for the packing and shipping of "Freon" refrigerant for electric refrigeration

The refrigerator mechanism. The essential processes in the operation of an electric refrigerator are relatively simple to understand, but the mechanism which controls them is rather complicated and delicate. The refrigerant, in the liquid state, is placed in the refrigerating mechanism in the factory. Every refrigerator is equipped with a temperature-regulator (thermostat), which starts and stops the motor. Once the motor is started, the entire mechanism is put into operation.

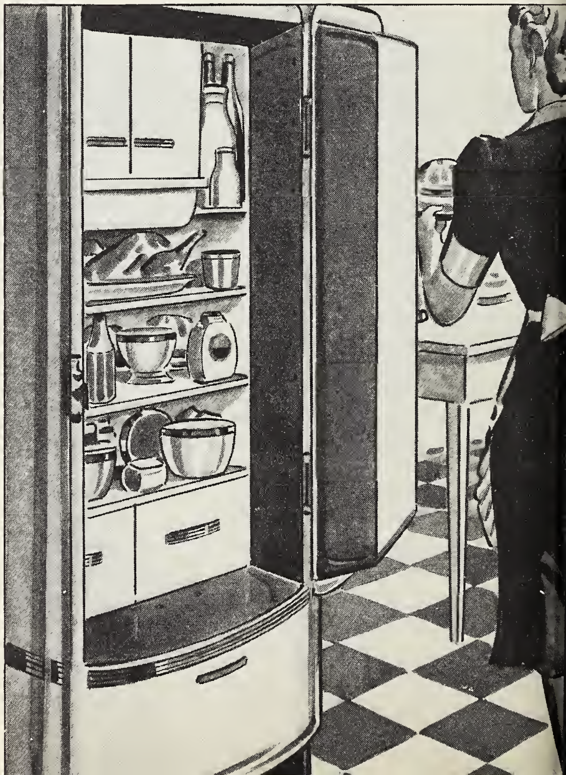
The liquid refrigerant flows into the evaporator coil, or cooling unit, where it changes back to a gas. When the liquid evaporates, it absorbs heat from the surrounding area, whether it be the ice-cube pans, the air, or the food. Thus the contents of the refrigerator are cooled. The evaporation of the liquid refrigerant continues until the thermostat shuts off the motor.

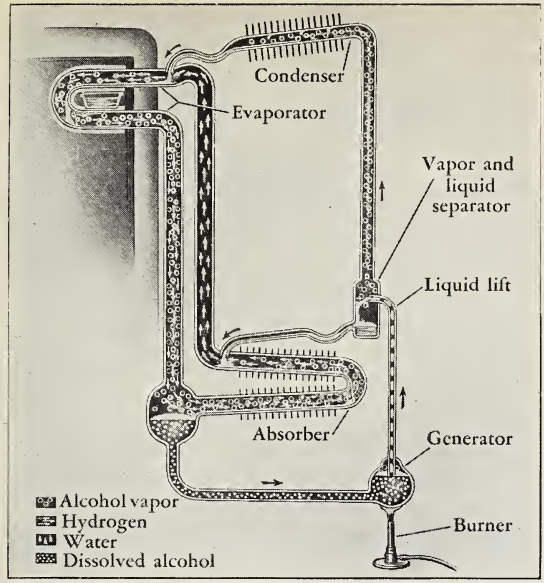
The gas coming from the evaporator is immediately converted back to a liquid by the compressor, which was set into operation automatically at the same time that the liquid refrigerant began to evaporate. The heat which is generated by compressing the gas, which is the same amount of heat as that absorbed by the liquid when it evaporated, is removed from the compressor coil, or radiator, by a fan or by the natural circulation of the air. Thus the refrigerant goes through a complete cycle—from a liquid to a gas and back to the liquid state. Not all the liquid goes through this cycle every time the refrigerator goes on; only that portion is evaporated, compressed, and condensed which is necessary to lower the temperature of the food compartment to the temperature set by the thermostat. The basic scientific principle upon which the cooling in a refrigerator is produced is the principle that the evaporation of a liquid is a cooling process. To change a liquid into a gas, heat energy must be absorbed. In a refrigerator this heat is absorbed from the contents of the food compartment.

The drawing on page 375 shows the location of the main parts of a mechanical refrigerator. The motor, compressor, and radiator are usually enclosed in the base of the refrigerator. This enables the heat, due to the compression and condensation of the refrigerant, to be discharged outside the food compartment. The evaporator, or cooling coil, is located in the upper part of the food compartment.

The modern mechanical refrigerator is practically foolproof and troubleproof. The manufacturing tendency is to produce sealed-in units which will run automatically for years without even oiling. They are guaranteed to run efficiently for from five to ten years, and after that time the consumer may, if necessary, purchase a new unit or a factory-rebuilt

One of the most uneconomical and inefficient practices in using any kind of refrigerator is to allow the door to remain open





Servel Electrolux

This diagram shows how it is possible for the modern gas refrigerator to cool with heat. Can you explain how this is possible?

unit. Leakage of the refrigerant practically never occurs. The consumer is protected from this hazard by the fact that most refrigerants have an odor, either of their own or one that has been added, which gives warning of leakage. Some compounds, such as methylene chloride, are not poisonous. Noise from the motor is not a disturbing factor in the modern electric refrigerators.

EXERCISES

1. What substances are used as refrigerants in an electric refrigerator? Give their formulas.

2. How does a substance such as liquid ammonia serve as a refrigerant?

3. List and describe the essential parts of an electric refrigerator.

4. Trace the flow of heat from warm food placed in an electric refrigerator until the heat is dispelled by the refrigerator.

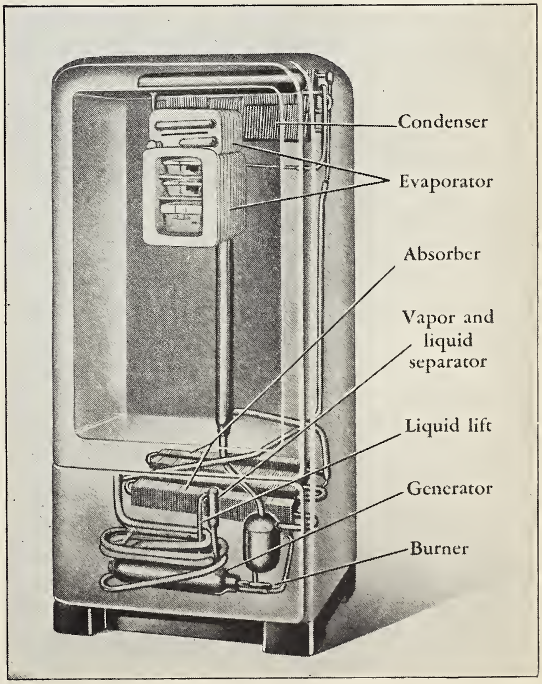
Problem 5. How does a gas refrigerator work?

The same principle underlies both gas and electric refrigeration. The essential principle of a gas refrigerator is the same as that of an electric refrigerator, namely, that the evaporation of a liquid produces a cooling effect. The difference between the two types of refrigerators is in the method of compressing the gas to the liquid state. The gas refrigerator operates without a motor, and there are no valves or moving parts. The refrigerant is compressed by heat. Ammonia gas (NH_3) dissolved in water is the refrigerant most generally used in gas or kerosene refrigerators. The diagram at the left illustrates the process of gas refrigeration.

Cooling by heating. The heat from the burning of gas or kerosene drives off the ammonia gas from its water solution. Since the space in which it is enclosed in the unit does not enlarge and the ammonia gas is being driven into it continuously, the gas must be compressed by this process. The compressed gas is led through a cooler, which condenses it to the liquid state. The liquid ammonia then flows by gravity to the evaporator, where hydrogen gas is present, which lowers the pressure so that the liquid ammonia can evaporate to a gas. The evap-

The operating unit installed in a modern gas refrigerator

Servel Electrolux



oration of the liquid ammonia produces the cooling effect; therefore this portion of the unit is in the food compartment. The evaporated ammonia gas is then dissolved by water and flows back to the starting point. Here the heat from the flame again drives it out of solution, and it starts again on its cycle. A thermostat is used to control the flame. When the temperature in the food compartment rises above the temperature set on the thermostat, the thermostat automatically turns on the gas flame, causing the cooling action to start. When the desired temperature is obtained, the thermostat shuts off the flame. The condenser in a gas refrigerator may be water-cooled or air-cooled. The latest models are air-cooled in order to avoid expensive installation and operation. The remarkable thing about the gas refrigerator is the fact that once the ammonia, hydrogen, and water are sealed into the unit, under the proper pressure, there is nothing to get out of order, since there are no moving mechanical parts. Provided there are no leaks in the system, which is generally guaranteed by the manufacturer, the only thing which goes in and out of the system is heat energy.

The burner which supplies the heat energy for compressing the ammonia sometimes needs attention and cleaning. The public-service companies of some localities maintain experts who are available for this service. Where this service is not available, the burner should be checked regularly to see that the air passage and flue do not become clogged with soot or other dirt.

Refrigerators which use kerosene as a fuel are in popular demand for farm homes which do not have access to electricity or gas. They are operated automatically, except for the replenishing of the kerosene, by a continuous flame, or pilot light, which turns the regular flame on and off. They consume approximately a gallon and a half of kerosene per day under normal operating conditions.

EXERCISES

1. How does a gas refrigerator differ from an electric refrigerator?
2. Explain how it is possible to cool by heating.
3. What refrigerant is used in gas refrigerators?
4. How does a thermostat work?

Problem 6. What are the relative merits of the different kinds of refrigerators used in the home?

The merits of the different kinds of refrigerators have been aptly summarized thus:[1]

Ice Refrigerators

Advantages

1. Lower first cost.
2. No mechanism to get out of order.
3. Less accumulation of food odors.
4. Somewhat higher humidity in cabinet.
5. No possibility of freezing food.
6. No noise.

Disadvantages

1. Bother of being at hand to admit iceman.
2. Inefficient and expensive service in some communities may make operating costs high.
3. Bother of emptying drainpan unless drainpipe is installed.
4. Not able to leave food in refrigerator for several days unless ice capacity is large or iceman has access.
5. Not possible to make frozen desserts.
6. No way to check on weight of ice delivered unless it is cut into standard-size cakes.

Electric Refrigerators

Advantages

1. Greater convenience.
2. Capable of maintaining temperatures at low levels in hot weather if mechanism has sufficient reserve capacity.
3. Desserts and salads may be frozen in evaporator.

Disadvantages

1. Higher first cost.
2. Possibility of needed costly repairs.
3. Uncovered food dries out more quickly.
4. Accumulation of food odors unless food is covered.
5. Possibility of freezing food in cabinet.
6. Noise, varying with type of refrigerator.
7. Some danger from leakage of refrigerant and production of possible toxic effects on people in house. Some refrigerants are explosive. Some are anesthetics.

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[1] Quoted from Better Buymanship Leaflet No. 19, copyright by Household Finance Corporation, Chicago.

Gas Refrigerators

Advantages

1. Same ones as for electric.
2. No moving parts to get out of order.
3. No noise.

Disadvantages

1. Same as electric, with exception of noise.
2. Burner needs occasional cleaning and adjustment.

Kerosene Refrigerators

Advantages

1. Same as gas.

Disadvantages

1. Same as gas.
2. Kerosene tank must be filled.

A written statement from the dealer which guarantees an average operating cost should be demanded. The actual cost of operation can be accurately checked with a watt-hour meter, which is supplied, upon request, by many dealers.

EXERCISES

1. What important advantages does an ice refrigerator have?
2. What important advantages does an electric refrigerator have?
3. What important advantages does a gas refrigerator have?
4. What is the most significant disadvantage of each type of refrigerator?
5. Which type of refrigerator would you recommend for your home? Why?

Problem 7. How may a refrigerator be maintained at maximum efficiency?

Care of refrigerator important. Even the best-constructed and most economical refrigerator of any kind may be used improperly and thus be a menace to health and also be costly. Careful attention to the care of your refrigerator pays.

Cleaning. Every refrigerator should be kept scrupulously clean. The inside walls and shelves should be cleaned once a week with a washing soda or sodium bicarbonate solution. After this solution has been used, the refrigerator should be rinsed with clear water and dried thoroughly. It is not necessary to use hot water. This practice is inadvisable because it heats the walls unnecessarily and results in uneconomical operation. Any spilled food, such as milk or juices, should be immediately removed and the spot cleaned. Millions of germs may accumulate in a few days from one drop of milk if the temperature is right. In ice refrigerators, be sure to keep the drain spotlessly clean.

Location. The refrigerator should be placed in the coolest part of the room away from stoves, radiators, and direct sunlight. An electric or gas refrigerator should stand two or three inches away from the wall so as to allow adequate removal and circulation of the warm air which comes from the condenser. Porches and cellars are poor locations for any refrigerator. Do not place a refrigerator in a drafty location.

Defrosting. In electric or gas refrigerators the frost should not be allowed to collect on the evaporator coils to too great a depth, as this makes the absorption of heat much more difficult. The encrusted ice acts as an insulating agent about the cooling coils. The cooling unit should be defrosted according to the manufacturer's directions. In ice refrigerators it is a bad practice to wrap the ice in paper to conserve it. Why?

Removing food from the refrigerator. The easiest way to make the refrigeration bill high is to form the habit of leaving the refrigerator door open long at a time. Merely opening and closing the door causes the temperature of the food compartment to rise two or three degrees. This rise of temperature will vary according to the temperature of the air in the room. Try to form the habit of removing all the articles or dishes with one opening instead of opening the door separately for each thing. When the door is shut, be sure that it is tightly shut if economical operation is desired.

It is an unwise practice to put hot food in a refrigerator because it acts as an extra source of heat and causes that much more heat to flow into the cooling element or ice. In using an ice refrigerator, it is much more economical and safe to keep the ice compartment full of ice at all times.

The proper storage of food, cooked or raw, is just as important to health as the proper cooking of food.

EXERCISES

1. Why is scrupulous cleaning important in a refrigerator?
2. How should a refrigerator be cleaned?
3. Explain how it is possible for frost on the coils of an electric refrigerator to act as an insulator and keep the refrigerator from working efficiently.
4. How should food be removed from a refrigerator and placed in it?

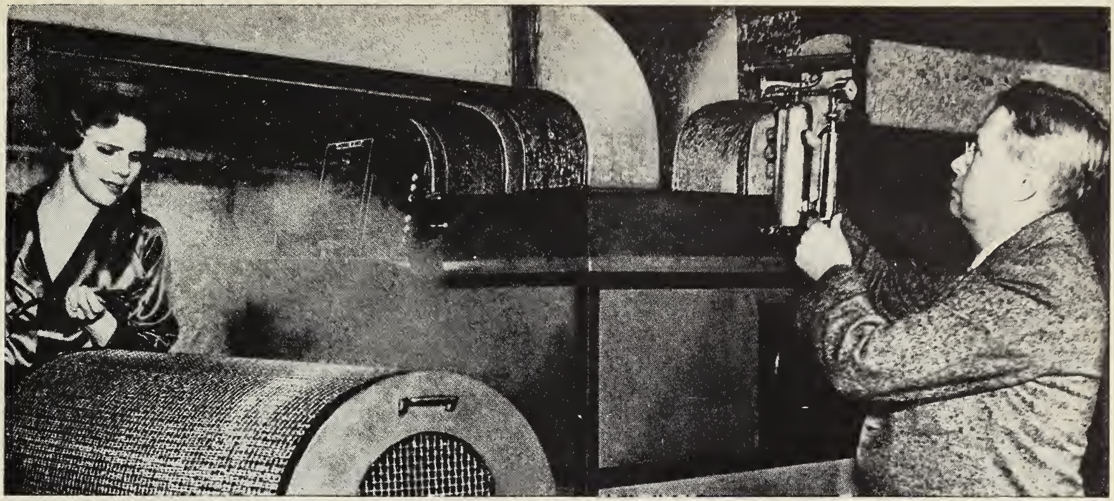
Problem 8. How may mechanical refrigeration be used in cooling the home?

The meaning of air-conditioning. Many people confuse air-conditioning with air refrigeration. These two things are not necessarily the same, because it is possible to condition air without cooling it, and it is also possible to cool air without conditioning it. Briefly, air-conditioning means the control of the temperature, humidity, circulation, ionic content, and cleanliness of the air within a room or building. To condition the air of a home fully necessitates heating it in the winter as well as cooling it in the summer. It is wrong to think of air-conditioning as simply cooling the home during the warm summer months.

Why is air-conditioning necessary? Providing pure conditioned air to their homes is something that many homeowners neglect. Few people realize that the average person breathes into his body thirty-five pounds of air every twenty-four hours and that this is seven times the amount of the food intake. It is just as important that the air intake be pure as that the food intake be clean and free from contamination. The heating plant of your home should provide clean, properly humidified, and properly circulated air if air-conditioning is desired. Simply heating the air is insufficient. Scientific experiments prove that comfort in a room is much more dependent on the temperature, humidity, and circulation of the air than on its oxygen or carbon dioxide content. The oxygen content of air may drop to 13 per cent, and the carbon dioxide content may rise to 5 per cent, without decreasing comfort or being harmful to health. If the air is circulating adequately, comfort is determined by the relationship between the temperature and the humidity. A high temperature is more comfortable when the humidity is fairly low, and a low temperature is more comfortable if the humidity is relatively high. The best relative humidity for com-

The modern office may be kept cool in the summer by means of a small single-unit air-conditioning apparatus which looks like a piece of furniture

Eaton and Morse, Inc.



Ewing Galloway

This photograph shows a newly designed air-conditioning apparatus being tested. A cloud of impurities is being sprayed into the filter, which eliminates 98.2 per cent of the dust. The man at the right is taking out a sample of conditioned air from the warm-air duct with a dust-counter. The unit is working here in conjunction with a hot-air heating plant

fort for the average temperature is between 40 per cent and 60 per cent. The circulation of the air is sufficient if each person in a room is provided with 10 cubic feet of air per minute or if the air in a room is changed from one and a half to four times an hour, depending on the number of persons in the room and the odors to be removed. The proper temperature of a room is dependent on many factors: the amount of water vapor, or relative humidity, of the air, the outside temperature and the inside wall temperature, and the number of occupants and their physical activity. It is not generally known that a human being gives off a surprising amount of heat. A person, at rest, will radiate about 400 Btu per hour, whereas a person engaged in violent exercise gives off about 1500 Btu per hour. These facts about air-conditioning are given so that you may realize that it is no simple job to air-condition a home properly.

The operation of air-conditioning units. Air-conditioning apparatus, including cooling apparatus, is available in the form of units for individual rooms or duct systems for an entire home. Most duct systems are designed to cleanse, humidify, warm or cool, and forcibly circulate the air in the required amounts. Some of the units for individual rooms do the same thing for one room as the duct systems do for an entire house. Others simply refrigerate the air and blow it into the room.

The air-cooling mechanism of an air-conditioning unit or system is similar to that in a mechanical refrigerator. There is an evaporator, or cooling coil, in which the compressed refrigerant changes to a gas, thus absorbing heat from the air which passes over the coil. A fan forces this cooled air into the rooms. The whole system, even in the unit type, must be of greater capacity than that of the electric refrigerator to provide for the cooling of the large masses of air.

The cost of operating an air-conditioning plant depends on many factors, such as the extensiveness of the system, the "occupancy load," the difference between the inside temperature and the outside temperature, and the efficiency of the plant. In general, it costs as much to cool the inside air to 75° F in the summer as it does to heat it to 72° F in the winter. In other words, to maintain a completely air-conditioned home all year would require about the same amount of money each month for fuel or electricity. To air-condition a single room with a unit-type system is more costly, in initial outlay and maintenance, than to heat a single room. This is because it is difficult to isolate and insulate a single room properly.

Before buying any air-conditioning unit or system, one should receive bids from two or more reliable dealers who have had competent engineers figure all aspects of the situation. The guarantees and facilities for servicing the equipment should be carefully examined before purchasing.

Use of air-conditioning. Air-conditioning is more widely used in theaters, restaurants, and stores than in homes. The cost of installation for owners of moderately priced homes is almost prohibitive. However, as the cost decreases, air-conditioning will become more widely used.

Where there are hay-fever or asthma sufferers in the home, air-conditioning is well worth the cost. Some hay-fever sufferers have been found to obtain complete relief if permitted to sleep in an air-conditioned room.

"Dry Ice"—solidified carbon dioxide. A discussion of refrigeration would not be complete without a description of "Dry Ice," although it has found very little application in home refrigeration.

"Dry Ice" is solid carbon dioxide (CO_2). It has a temperature of $-110°$ F, and the term *dry* is used because it does not melt to form a liquid. Instead the solid ice passes directly into the gaseous state. It is said to sublime.

"Dry Ice" is made by first compressing and cooling carbon dioxide gas until it liquefies. When the pressure reaches 52 atmospheres, it is suddenly reduced to 1 atmosphere. Thus the liquid CO_2 evaporates, causing additional cooling and resulting in the formation of CO_2 "snow." This snow is compressed into thin blocks, which are used for commercial purposes.

"Dry Ice" is especially valuable in refrigeration because of its low temperature and its dryness. Foodstuffs refrigerated with "Dry Ice" can be transported in paper cartons because it does not melt to form a liquid. The shipping weight of foods packed in "Dry Ice" is much less than when they are packed in ordinary ice. Therefore the transportation cost is less.

Quick-frozen foods are always packed in "Dry Ice" after they are frozen, so that they may be transported without spoilage. The transportation of ice cream has been revolutionized by the use of "Dry Ice."

You should be extremely careful in handling "Dry Ice," as it will destroy the tissue if it remains in contact with the skin for any length of time. Never put it in your mouth.

EXERCISES

1. Define the term *air-conditioning.*
2. How much air does the average person breathe into his body every twenty-four hours?
3. What factors in the condition of the air within a home affect comfort?
4. What relative humidity of air is most comfortable?
5. How many British thermal units does the average person radiate in a day?
6. What is the source of the British thermal units which are radiated by the body?
7. Explain the operation of an air-conditioning unit.
8. What is "Dry Ice"? Why is it called "dry"?
9. What uses are made of "Dry Ice"?

PROBLEMS FOR FURTHER STUDY

1. What information can you get from the labels of refrigerators sold in your communities?
2. What information should be on the labels of electric, gas, and ice refrigerators?
3. What is the average monthly cost of operating the refrigerator in your home?
4. What is meant by the terms *heat of vaporization*, *heat of fusion*, and *specific heat*?
5. What is the difference between heat and temperature?
6. Are the best insulating materials for refrigerators also the best ones for houses? Why?
7. How are frozen foods prepared? Do such foods have the same nutritional value as fresh foods?
8. The wrapping of ice in paper makes it last twice as long in your ice refrigerator; yet this is an uneconomical practice. Why?
9. Can air-conditioning systems be applied to a modern automobile? Why?
10. Why is the air always cool near a waterfall?
11. Why is it necessary to use salt with the ice in freezing ice cream?
12. What refrigerants are used in the various brands of electric refrigerators?
13. How do porous jugs and canvas-covered containers keep water cool?
14. How does refrigeration ensure better health?
15. What is the difference between a rotary and a reciprocating compressor?
16. What are the sources of carbon dioxide?

UNIT EXERCISES

A. The statements which follow are incomplete. On a separate sheet of paper write whatever is necessary to complete each statement correctly. Do not write in this book.

1. The most desirable temperature for the interior of a home refrigerator is approximately --(?)--.

2. The formula for "Dry Ice" is --(?)--.

3. A refrigerant used in home electric refrigerators is --(?)--.

4. The refrigerant used in most commercial refrigerators is --(?)--.

5. Bananas keep best at a temperature of approximately --(?)--.

6. The rate at which fruits ripen is --(?)-- for each rise in temperature of 18° F.

7. When food deteriorates, --(?)-- changes and --(?)-- changes take place.

8. Air circulates in a refrigerator because warm air is --(?)-- dense than cold air.

9. To change a gram of ice to a gram of water at the same temperature requires --(?)-- calories of heat.

10. The common types of refrigerators used in the home are ice, --(?)--, and --(?)--.

11. In the evaporator of an electric refrigerator the refrigerant changes from the --(?)-- state to the --(?)-- state.

12. The formula for dichlorodifluoromethane is --(?)--.

13. In a gas refrigerator the refrigerant NH_3 is driven off from its water solution by --(?)-- the water with a gas flame.

14. In an electric or a gas refrigerator a --(?)-- is used to control the flow of the refrigerant through the unit.

15. The interior of a refrigerator should be cleaned once a week with a weak solution of --(?)--.

16. Opening and closing the door of a refrigerator once will raise the temperature of the food compartment about --(?)-- degrees F.

17. An average person consumes about --(?)-- pounds of air per day.

18. The best relative humidity for comfort is from --(?)-- to --(?)-- per cent.

19. A person engaged in violent exercise will give off about --(?)-- British thermal units per day.

20. The two factors of the condition of the air, in addition to temperature, which greatly affect comfort are --(?)-- and --(?)--.

B. Some of the statements which follow are true, and some of them are false. On a separate sheet of paper write the word *true* for those which are true and the word *false* for those which are false. Do nothing for those about which you are doubtful. Rewrite the false statements so that they are true.

1. All foods should be maintained at about the same temperature to prevent spoilage.

2. Electric refrigerators work on the principle that the evaporation of a liquid to a gas is a cooling process.

3. Warm air is more dense than cold air.

4. SO_3 is a refrigerant used in electric refrigerators.

5. In the compressor of an electric refrigerator heat is absorbed by the refrigerant.

6. The automatic controlling device on an electric or a gas refrigerator is known as a thermometer.

7. When a liquid evaporates heat is given off.

8. Evaporators in electric refrigerators radiate heat.

9. Each type of refrigerator has some advantages over the other types.

10. Gas refrigerators have the disadvantage of being noisy.

11. An electric or a gas refrigerator should be defrosted about once a week.

12. Air-conditioning and air refrigeration mean the same thing.

13. The air-cooling mechanism of an air-conditioning unit is similar to that of a mechanical refrigerator.

14. "Dry Ice" has a temperature of about 50° below zero.

15. Quick-frozen foods are packed in "Dry Ice."

REFERENCES FOR FURTHER READING

Hausrath, Alfred H., Jr., and Harms, John H. *Consumer Science.* The Macmillan Company, New York, 1939.

Hull, H. B. *Household Refrigeration.* Nickerson and Collins Company, Chicago, 1933.

Voorhees, Gardner T. *The Absorption Refrigerating Machine* (Second Edition). Nickerson and Collins Company, Chicago.

When You Buy a Refrigerator. Consumer Purchasing Leaflet No. 3, American Home Economics Association.

UNIT 25

The Chemistry of Sanitation in the Home

Probably the most important reason why there is less sickness today than formerly is that our homes, the places where we eat and sleep, are kept more sanitary. We can expect to live longer because we live in cleaner homes. Science has taught us the necessity of disposing of the waste materials of the home, of keeping our homes well lighted and well ventilated, and of keeping the furnishings free from dirt.

The chemist has provided us with many materials, such as soaps, bleaches, disinfectants, oils, waxes, and polishes, for use in maintaining a clean, healthy home.

Only during modern times has much thought or emphasis been given to providing sanitary surroundings in which to live. Indeed, the modern bathroom was generally unknown during the Spanish-American War. It was common for people to bathe in a round washtub, usually placed in the kitchen—and then only on Saturday night. Even the use of soap for general laundry purposes is relatively new. Very little soap was used during the colonial period. Today over three billion pounds of soap are used annually in the United States alone.

Modern manufacturing processes have made clothing so cheap that the average person has several changes of clothing, so that he is able to have his clothes cleaned more often. Cleanliness of body and clothing and of one's surroundings has added much to the health, comfort, and happiness of people of today.

PURPOSES TO BE ACHIEVED

1. To discover the part that chemistry plays in making sanitary homes.
2. To learn the best ways of maintaining sanitation in the home.
3. To help you to select the proper and most economical cleaning materials.
4. To learn how to combat insects and rodents which may invade the home.
5. To aid you in selecting the materials for a good home medicine cabinet.

Chemistry has contributed many substances and scientific practices which make possible clean and healthful homes

Delano from Farm Security Administration

E. I. Du Pont de Nemours & Co.

A photometer with a sphere reflectometer attachment, used for measuring reflection from any surface for various wave lengths of light. The machine is used in the laboratory to test detergency, or cleansing power, by measuring the brightness of scoured pieces

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PROBLEMS TO BE SOLVED

1. What are the chemicals used in laundering, and how are they made and used?
2. How should walls, woodwork, and windows be cleaned?
3. What are the sanitary methods of waste disposal in the home?
4. How should the plumbing of the home be cared for?
5. What should a good home medicine cabinet contain?
6. How may the home be kept free of rodents and insects?

Problem 1. What are the chemicals used in laundering, and how are they made and used?

How are soaps made? Early pioneers obtained the fat for making their own soap from the rinds of bacon and ham and from the fats collected from cooking. This was mixed with a liquor obtained by pouring water through wood ashes a number of times. The liquor was alkaline, containing sodium and potassium carbonate. These chemicals reacted with the fat, forming a crude soap. Soap is still manufactured in a similar manner by some farmers for home laundering except that lye may now be purchased in almost any grocery store.

The large-scale manufacture of soap was not possible until the discovery of practical methods of manufacturing alkalies on a large scale. This did not take place until about 1800.

Soaps are compounds formed by the reaction of bases with fats, chemically known as fatty acid esters. The three most important fatty acid esters are

palmitin ($(\text{C}_{15}\text{H}_{31}\text{COO})_3\text{C}_3\text{H}_5$),
stearin ($(\text{C}_{17}\text{H}_{35}\text{COO})_3\text{C}_3\text{H}_5$),
and olein ($(\text{C}_{17}\text{H}_{33}\text{COO})_3\text{C}_3\text{H}_5$).

They are found in lard, tallow, olive oil, cottonseed oil, and other animal and vegetable fats or oils.

The choice of fats or oils for soapmaking is determined partly by the cost of the materials. Few soaps on the market are made from one fat only. Manufacturers have discovered formulas which produce soaps with a desired firmness, suds-producing power, solubility, washing power, etc.

The process of treating fats with bases or alkalies is called saponification. The alkali used in making firm, or hard, soaps is lye, or sodium hydroxide (NaOH). The process takes place in large cylindrical vessels. The reaction may be illustrated by an equation using one of the fats, stearin, in its chemical union with lye:

$$\overset{\text{stearin (fat)}}{(\text{C}_{17}\text{H}_{35}\text{COO})_3\text{C}_3\text{H}_5} + \overset{\text{lye}}{3\,\text{NaOH}} \longrightarrow \overset{\text{soap}}{3\,\text{C}_{17}\text{H}_{35}\text{COONa}} + \overset{\text{glycerin}}{\text{C}_3\text{H}_5(\text{OH})_3}$$

This huge kettle is charged with a quarter of a million pounds of olive, palm, and coconut oils. These oils are boiled with caustic soda to form soap and glycerin

Colgate-Palmolive-Peet

Colgate-Palmolive-Peet

Samples of soap boiling under reflux condensers for the determination of free alkalinity

Graining, in which operation common salt (NaCl) is added, follows. During this process the soap becomes insoluble in the brine and separates from the solution. The soap may be washed several times with brine to rid it of free alkali.

The molten soap may be run into large frames from which bars may be cut, or it may be run over cold rollers, producing thin sheets which are scraped to form soap chips. The molten soap may also be squirted from a nozzle as a spray into hot air to form powdered soap.

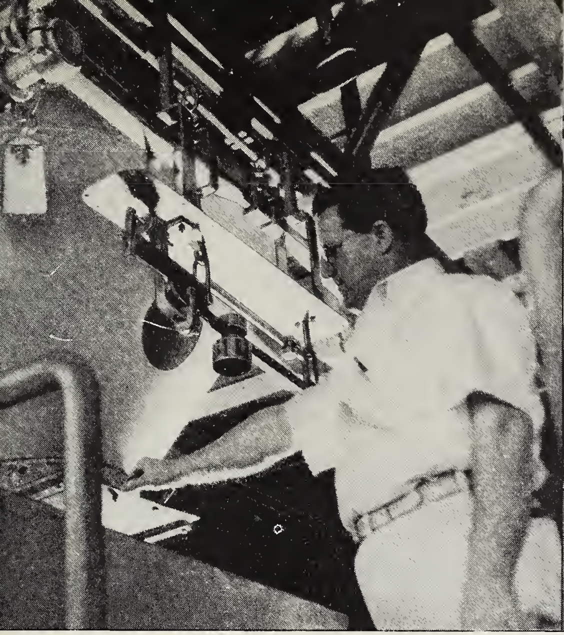
Soft, or liquid, soaps are made by using potassium hydroxide (KOH) instead of lye. These are often used in making shampoo soaps and in soap-dispensers. The glycerin formed remains in the soft soap but adds no value to the soap.

What fillers are used in soaps? Very often certain foreign materials are added to the soap as it leaves the kettle. These fillers may be such inert adulterants as chalk and sulfates of sodium, calcium, and barium; or sodium silicate may be used as a filler. With the exception of sodium silicate, these are all valueless. Sodium silicate (Na_2SiO_3), or water glass, gives firmness to soap and enables it to hold more water. A small amount is permissible in laundry soap because it softens hard water and prevents the formation of insoluble curds.

The use of rosin in making laundry soaps. Rosin, although not a fatty acid, reacts with lye to form a sodium salt which resembles soap in many respects. It is soluble and has a high frothing power; for these reasons it is added to many laundry soaps. Soaps containing rosin are yellow in color and form suds rather easily. The cleansing power of rosin soap is much lower than that of ordinary soap, and the presence of rosin in any quantity is undesirable. If soap contains more than 15 per cent rosin, it is known as a low-grade soap. If the water in which the clothes are washed is hard, there is danger that curds will form from rosin soaps and discolor the clothes.

What are soap powders and washing powders? Soap powders are not to be confused with powdered soap, which is merely soap in powdered form. Most soap powders are mixtures of soap and alkali substances known as builders, such as sodium carbonate, trisodium phosphate, borax, and sodium sulfite. Sodium carbonate is most frequently used. Some washing powders also contain a bleaching agent, such as sodium perborate. These usually are called oxygen washers and often contain part of the word *oxygen* in the commercial name. As a rule, the cheaper the washing powder, the larger the proportion of alkali present. The builder is added to help to soften hard water and to act as a cheap detergent, or cleansing agent. It should be remembered, however, that the builder is a less efficient cleansing agent than soap.

What are synthetic, or soapless, soaps? Recently there have appeared on the market several new products, such as "Drene" and "Dreft," which, although serving the purposes of soaps, are really not soaps at all. Chemically, these products are made by treating lauryl alcohol ($C_{12}H_{25}OH$) with sulfuric acid and sodium hydroxide, which results in a compound known as sodium lauryl sulfate ($Na \cdot C_{12}H_{25} \cdot SO_4$). Lauryl alcohol is one of the higher alcohols, produced by hydrogenating the fatty acids obtained from vegetable oils. Sodium lauryl sulfate shares with soap the characteristic of making foamy suds in water and therefore is a



Procter and Gamble Company

The ingredients used in the manufacture of soap are oils, fats, and sodium hydroxide. These are measured out in exact amounts, as shown in this picture, before being poured in the soap kettles. The making of soap is an exact chemical process

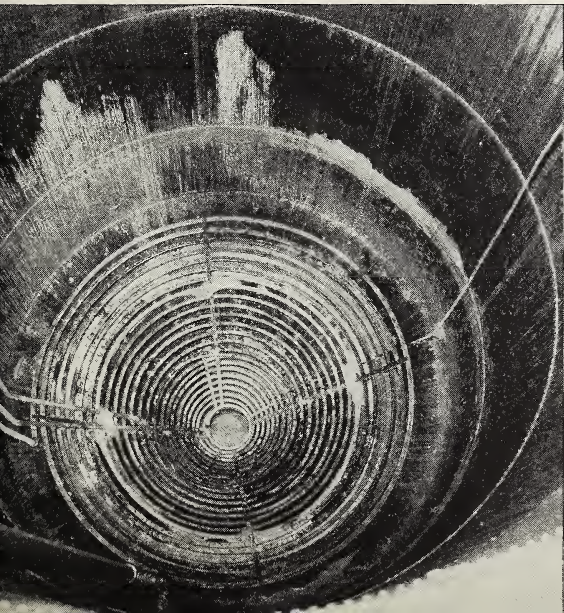
The materials are cooked for two days in large soap kettles, heated by steam pipes, where the fats and oils combine with the sodium hydroxide to form the new substances—soap and glycerin

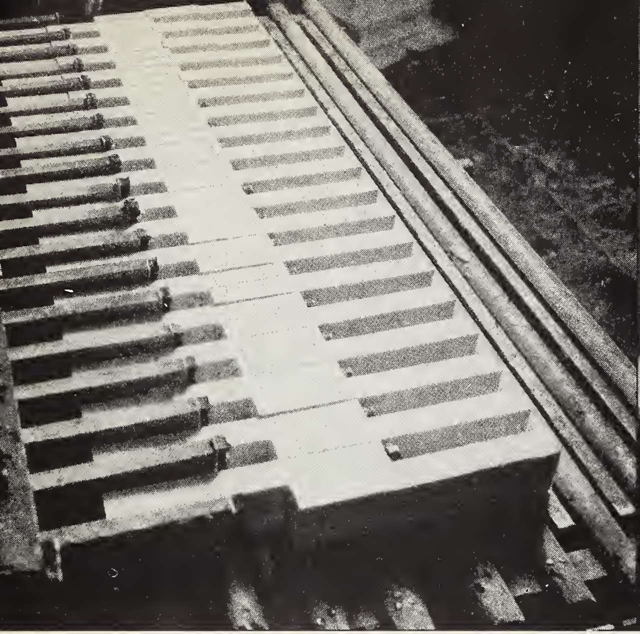
The Story of the Manufacture of Soap

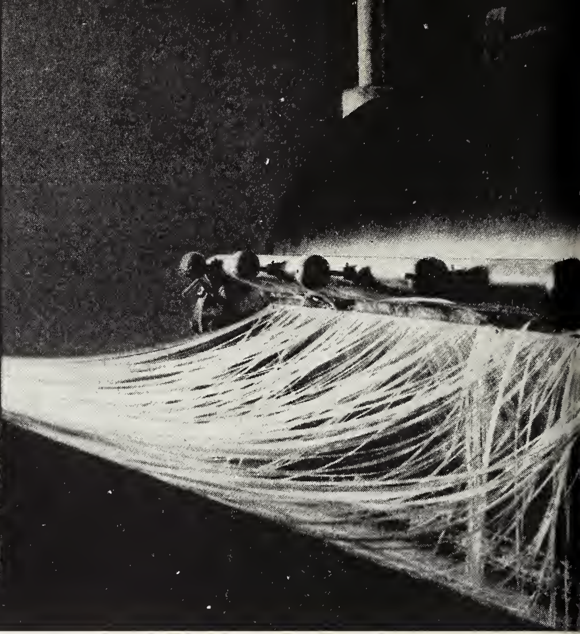
An interior view of a soap kettle. These kettles are three stories high. The concentric circles in the bottom are the steam pipes which heat the masses of soap

The soap is separated from the glycerin, excess chemicals, and water by the addition of salt. After this process the soap flows to flat iron frames, where it cools and solidifies

Procter and Gamble Company







Procter and Gamble Company

The large frames of soap are then cut into bars by means of taut piano wires, and the rough cakes are ready to be molded, stamped with the manufacturer's name, and wrapped ready for shipment

If milled toilet soap is desired, semisolid soap is rolled to a thin film, stripped off the rolls in ribbons, squeezed into pellets, mixed with perfume, compressed to a hard bar, cut, shaped, and wrapped ready for shipment

The Story of the Manufacture of Soap

For flake soap, the semiliquid soap runs into a trough, where a chilled roller picks up a thin film, which hardens. A large blade cuts thin ribbons of soap from these rollers

Highly trained chemists test each batch of soap. This chemist is shown taking a sample which he will test for free alkali, free fats and oils, and pure soap

Procter and Gamble Company

Du Pont Style News Service

Soapless soap is the chemist's latest contribution to the home laundry

Colgate-Palmolive-Peet

Fractionating column and still used to test some of the new soapless detergents

cleanser. It has the great advantage of working as well in hard water as in soft water, since no greasy curds are formed. At present the cost prohibits its use for general laundry purposes except in regions of very hard water or for fine silks, rayons, and woolens. It is usually sold in the granular form mixed with an inert substance, such as sodium sulfate, which acts as a diluent and reduces the cost so that it is within the price range of other cleansing agents.

How do soaps cleanse? Soap solutions owe their cleansing power to (1) the ease with which they wet dirty clothing, dishes, etc. and (2) the fact that they form emulsions with grease and prevent its return to the articles being washed. Soapy water penetrates and spreads over the surface of immersed articles much more readily than plain water; thus its wetting power is greater. Pure water will not dissolve grease, but soapy water forms an emulsion with grease, oil, or sugars. When dirt which is present in a film of grease and oil adheres to an article, it is removed as the grease and oil are emulsified by the soap. As long as there are suds in the water, the dirt and grease are held in suspension. If the suds break, the dirt and grease are precipitated upon the clothing again. Hence clothes should be removed from the water and rinsed before the suds disappear. Soaps lather more freely in warm or hot water. Also, fats melt at temperatures slightly above body temperature. Therefore warm soapy water possesses a greater cleansing, or detergent, power than cold soapy water.

What is bluing, and why is it used? Bluing is used to counteract the yellow or dingy color in clothes caused by careless rinsing or by lack of sunlight. Bluing may be bought in paste, liquid, or solid form. The type which is usually sold in ball form, to be tied in a cloth before being placed in the water, is often known as ultramarine blue. Though it occurs naturally in the mineral form, bluing may be manufactured by heating a mixture of kaolin, sodium carbonate or sodium sulfate, sulfur, and carbon. The resulting ultramarine blue is believed to have the formula $Na_7Al_6Si_6O_{24}S_2$.

Another bluing material, aniline blue, a coal-tar product, is sold in the crystal, liquid, or powder form. It is probably the best kind to buy for general laundry purposes. Prussian blue, or ferric ferrocyanide ($Fe_4(Fe(CN)_6)_3$), contains iron which, when this bluing is used with clothes from which the soap has not been thoroughly rinsed, may react with the alkali of the soap to form iron oxide. This iron oxide may be deposited as spots or streaks on the clothing.

Bluing should be added to the last rinse water in sufficient quantity to give the water a clear blue color.

What is laundry starch, and why is it used? You have learned that starch is a carbohydrate obtained from many vegetables. It has the formula $(C_6H_{10}O_5)_x$ and is secured principally from such grains as corn, wheat, and rice, though some is obtained from potatoes. The chief difference in the starch from each of these sources lies in the fact that the starch grains, or particles, are of different sizes. Cornstarch is used more often in laundering, though wheat starch will give a softer finish, and rice starch is sometimes used for very fine fabrics. A good deal of the starch on the market for laundering is a blend of different starches.

In preparing starch for laundry purposes, cold water is added first to separate the granules, after which boiling water is added. The mixture is boiled gently for five or ten minutes and strained through a clean cloth to remove lumps. White fabrics are usually dipped in this solution while it is still hot. Bluing is sometimes added to give it a slight blue tint. The garments are usually dipped in the starch bath immediately after having been wrung free of the rinse water. They should be turned wrong side out before being dipped in the starch. All the starch solution possible should be wrung from the goods.

Uncooked, or cold, starch solution is sometimes used on the cuffs, collars, or other parts of garments requiring a stiff finish. When the cuff or collar is ironed, the starch is cooked by the hot iron.

Starch is used to produce a smooth attractive finish to goods when they are ironed. It also adds body to a garment, filling the spaces between the fibers, thus helping to prevent dirt from adhering to the material. Most cotton goods contain starch as a filler when purchased. This is soon washed out by continued laundering. The starching of goods helps to replace this filler.

What effect does hard water have on soaps? Many natural waters contain chemicals which make them hard. These dissolved chemicals are usually $MgCl_2$, $MgSO_4$, $CaCl_2$, and $CaSO_4$, or the bicarbonates of these metals. Many of the towns, cities, and other communities of our country lie in hard-water belts. Soap is soluble in pure soft water and forms suds freely. But if the water is hard, the soap reacts with the magnesium or calcium salts to form insoluble soaps. The greasy curds in soapy hard water and the familiar ring around the bathtub are the result of insoluble soaps. The equation for such a reaction may be written as follows:

$$\overset{\text{soap}}{2\,NaC_{17}H_{35}COO} + \overset{\text{salt}}{MgCl_2} \longrightarrow \overset{\text{insoluble soap}}{Mg(C_{17}H_{35}COO)_2} + \overset{\text{salt}}{2\,NaCl}$$

If enough soap is added to hard water, a lather, or suds, can finally be produced. Suds will be formed after all the minerals causing the hardness have been precipitated. This is an expensive method of softening water and results in the waste of millions of dollars' worth of soap each year. In Unit 29 a convenient method of softening water in the home is described.

Many soaps and washing powders contain a filler which helps to soften hard water. Some of the fillers used in soap for this purpose are sodium carbonate, borax, and trisodium phosphate. These may also be bought in packaged form for use in softening water.

Sodium carbonate, sal soda, or washing soda ($Na_2CO_3 \cdot 10\ H_2O$), reacts with the calcium and magnesium ions to form insoluble salts which are precipitated from the solution:

$$Na_2CO_3 + MgCl_2 \longrightarrow 2\,NaCl + MgCO_3\downarrow$$

Borax and trisodium phosphate react in a similar way to soften hard water. Sal soda contains such a high percentage of water of crystallization that it is cheaper to use trisodium phosphate. This is especially true if you take into account the fact that the latter is a more efficient detergent.

It may be well to recall that the soapless soaps lather just as freely in hard water as in soft water. In regions where the water is extremely hard, it is often advisable to use this form of soap for laundry purposes.

What are bleaches, and how are they used? The most familiar bleaches used in the home are those made from chlorine. Chemically, these substances are essentially a sodium hypochlorite ($NaClO$) solution. This solution may be prepared by passing chlorine gas into lye ($NaOH$) or by the electrolysis of a brine solution. The commercial grades run from 4 per cent to 6 per cent hypochlorite by weight. There is little difference in the various brands on the market. The thrifty housewife will compare the cost of the various brands with the per cent of hypochlorite as shown on the label of the bottle. Javelle water may be prepared from chlorinated lime ($Ca(OCl)_2$), a white powder which is sold in most grocery stores. This bleach is prepared by stirring the powder in water and allowing the insoluble lime to settle to the bottom.

The bleaching action of sodium hypochlorite is not due directly to the chlorine, as might be thought. Sodium hypochlorite is rather unstable and gives up an atom of nascent oxygen readily.

$$NaClO \longrightarrow NaCl + [O]$$

The bleaching action is one of oxidation. The nascent oxygen oxidizes the dingy, yellow coloring substances, thus making the clothing clean and white.

Sodium hypochlorite may be added to the first rinse water, about one tablespoonful to each gallon of water. It is used with white cotton goods as a bleach. Colored clothes may be rinsed in this water if the colors are fast. This chemical may also be used as a stain-remover and as a household disinfectant. Bleaches should be used cautiously, at low temperatures, and never with silk, wool, synthetic fabrics, or leather.

EXERCISES

1. Explain how pioneer families made soap.
2. Name four kinds of fats or oils from which soap may be made.
3. Can you explain how soap may be made as a by-product in a city garbage-disposal plant?
4. Glycerin is a by-product in the manufacture of soap. Make a list of uses which may be made of glycerin.
5. How do soaps made from fat and potassium hydroxide differ in texture from those made from fat and sodium hydroxide?
6. Why do some soaps float in water? How are they made?
7. Why is water glass added to some soaps?
8. Why is rosin added to some laundry soaps?
9. What is the difference between powdered soap and washing powder?
10. Why does hard water have no effect on soapless soaps?
11. Explain how soap helps to clean clothes.
12. Why should toilet soaps be free of alkali?
13. Explain why bluing is used in washing white goods.
14. Look at the pictures on page 142 and explain how starch is manufactured.
15. What minerals make water hard?
16. Explain and write equations showing how washing soda softens hard water.
17. Explain the bleaching action of sodium hypochlorite.

Problem 2. How should walls, woodwork, and windows be cleaned?

Cleaning painted surfaces. Enamel-painted walls and woodwork, such as are found in many bathrooms, should be wiped frequently with a wall brush or with a clean dry flannel cloth tied over a broom. Occasionally the woodwork may be washed with warm soapy water, rinsed, and wiped dry with clean cloths. The soap should be a white neutral soap or soap powder. To prevent streaking, the rinse water should be changed frequently, and plenty of clean washrags should be used. Care should be used to remove all soap, as it might react with the paint if left to dry in contact with it.

If the woodwork is painted with a dull-finish paint, more care must be exercised, as there is a greater tendency for some soap to remain on the painted surface. White bar soap is better to use in this case because there is less danger of small undissolved particles remaining in the water, which might adhere to the paint. A little household ammonia (ammonium hydroxide) may be added to the water.

Many of the commercial wall-cleaners contain trisodium phosphate. These preparations are usually good cleansers, but if too strong a solution is used, there is danger of removing some of the paint.

Cleaning varnished or oiled surfaces. Varnished or oiled wood may be cleaned occasionally with a clean cloth moistened with linseed oil, turpentine, kerosene, or furniture oil. In general, shellacked wood should never be washed with water, but varnished wood may be if care is used to wipe it dry afterward.

Varnished hardwood floors may be cleaned with an oil mop or cloth. Oil for this purpose may be purchased in jars, bottles, or cans at grocery, department, or hardware stores. It is usually a petroleum derivative, colored and sometimes scented. A good economical floor oil may be prepared by dissolving a quarter-pound of paraffin wax in a quart of kerosene. Some hardware merchants keep this mixed for customers as paraffin floor oil. After wiping floors with such an oil, it is wise to go over the surface again with a clean dry cotton cloth for polishing.

When hardwood floors are waxed, excessive amounts of oil should not be used in cleaning, because the oil will tend to dissolve and remove the wax.

Linoleum may be mopped or washed with clear warm water. Soapy water should be used only occasionally when the floor is rather dirty, as the alkali of the soap may attack the colors of the linoleum if left in contact with the linoleum too long. The floor should always be rinsed with clear warm water after using soap. Wax is often used on linoleum, the best type being a water-soluble wax. A mop containing a slight amount of oil may be run over the floor daily to brush away the dirt which clings to the surface.

Wallpaper-cleaners are on the market which are plastic in nature. They sometimes contain a gum, such as gum tragacanth.

Window-cleaning. This task is dreaded by most housewives. The cloth used for cleaning and polishing windows, mirrors, and other glass surfaces is of the utmost importance. Care must be exercised to use one which will not leave lint on the surface. The water used should be clear. No soap should be used, as this leaves a film after drying. A little household ammonia added to the water is effective in cutting any grease particles which may be on the surface.

Professional window-cleaners generally use trisodium phosphate dissolved in water. A teaspoonful of the powder in a gallon of water is usually sufficient.

Rubbing alcohol mixed with an equal amount of water is effective in washing windows. A few drops of kerosene on a clean cloth may also be used to wipe windows free of dirt.

There are a number of commercial window-cleaners on the market. Some of these contain ethylene glycol, and others are essentially alcohol, glycerin, or a kerosene-water emulsion. They may be applied as a spray and wiped clean with a cloth.

EXERCISES

1. Why should walls which have been washed with soapy water be rinsed off well?
2. What are two other substances other than soap which may be used in washing woodwork?
3. Why should no soap be used in washing windows?

Problem 3. What are the sanitary methods of waste disposal in the home?

Keep the garbage pail clean. Perhaps the most neglected utensil in the modern home is the garbage pail. The food refuse and the warm, moist, dark atmosphere of the garbage pail are both ideal for the growth of germs. Often this receptacle is simply emptied and replaced without washing, which is another factor aiding in the growth of germs.

The best method of garbage disposal is to use an electric grinder, which disposes of the garbage by grinding it into small particles, which may then go out of the house as sewage. However, the cost of such an appliance is prohibitive for most home-owners.

If a garbage pail is used, a sanitary paper liner, which may be bought in grocery stores, is suggested. If these are not available, large paper grocery bags may be inserted in the pail and used effectively. The pail should be washed with soapy water and dried thoroughly each day. Sal soda is also an effective cleanser.

If the garbage is transferred to a larger vessel outside the house for collection, this receptacle should be given special attention. These unsightly cans are the breeding places of millions of flies in many cities; hence they should be cleaned daily. A good

Ewing Galloway

Uncovered garbage pails not only are unsightly but are a menace to health. They should not be tolerated. Burning garbage in incinerators is a good way to dispose of it

practice is to sprinkle a little chlorinated lime on the bottom of these cans to prevent flies from depositing eggs there. A little sodium hypochlorite, about three tablespoonfuls to each quart of warm water, is a good disinfectant for garbage cans. It should be washed around the sides and rim of the can and allowed to stand in the can for five or ten minutes. The can should then be rinsed and dried.

Empty tin cans should never be allowed to collect out of doors. The practice of putting them in a box in a corner of the yard or of throwing them on ashpits is a careless practice. Rainwater often collects in such cans—a perfect breeding place for mosquitoes. Flies find a happy breeding ground in these eyesores.

The sanitary neighborhood is one which gives careful consideration to the collection of the garbage and other refuse of its citizens. Every citizen owes it to his neighborhood to see that his premises are kept neat and sanitary.

EXERCISES

1. Explain how the garbage pail which is kept in the house, usually in the kitchen, may be kept in a sanitary condition.
2. What chemicals may be used to disinfect garbage pails?
3. Explain why most of the flies and mosquitoes in cities may be traced to improper garbage disposal.
4. How do cities protect their citizens in regard to garbage disposal? Can you suggest ways in which your city could be of more service to its citizens in this matter?

Problem 4. How should the plumbing of the home be cared for?

Know your plumbing system. Each member of the household should be familiar with the shutoff valves of the water system in the home, so that in case of excessive leakage or the bursting of pipes the water may be shut off until repairs can be made. These valves should bear a tag stating their use or function. All the faucets in the house should be opened as soon as the main shutoff valve is closed.

Draining pipes to prevent freezing. If the house is to remain unoccupied and unheated during the winter, there is danger that the water will freeze and the pipes will burst. The main shutoff valve should be closed and all faucets opened. All remaining water should be drawn off through the drain valve. Water should be drawn or flushed from the water closets. The U-shaped water traps should be drained if possible. If this cannot be done, a quart of radiator or rubbing alcohol may be poured into the sink and into each toilet bowl and water closet. This produces a liquid which will not freeze at usual winter temperatures.

Water traps are in reality water seals which prevent the obnoxious gases of the sewer from entering the house.

The cleaning of water and grease traps. Special brushes are available for cleaning the traps of water closets. All the newer water-closet bowls are made of porcelain or pottery and should be cleaned daily. Stains are hard to remove if the bowls are not cleaned regularly. Waste materials which are not easily disintegrated by water should never be flushed down the sewer, as they may get caught on the irregular points which are found inside all sewer pipes.

When a water trap becomes clogged and the water will not run out, a soft-rubber-cup plunger may be placed over the opening and the plunger worked up and down. The trap under the kitchen sink is likely to clog with hardened grease. At the bottom of the trap is a cleanout plug. A bucket may be placed under this trap, the plug removed, and the grease or solids removed with a wire. It is a good plan, however, to allow boiling water to run through the sink every few days to melt and remove this grease before it becomes troublesome. If this does not work, potash lye (KOH) dissolved in boiling water may be poured down the sink. The KOH reacts with the grease to form a soluble liquid soap.

Some commercial drain-cleaners contain lye and small pieces of aluminum. The aluminum reacts with the NaOH when mixed with water to form hydrogen gas:

$$6\,NaOH + 2\,Al \longrightarrow 2\,Na_3AlO_3 + 3\,H_2$$

The churning action of the escaping gas aids in loosening the grease, making it possible for the lye to act upon the grease. The objectionable odor and the fine mistlike spray of lye solution which is given off when a cleaner of this type is used are disadvantages of this drain-cleaner.

EXERCISES

1. Is there a place where the water coming into your home or apartment may be turned on and off?
2. Explain how you can protect the plumbing in your home from freezing when you are going away for a considerable length of time in the winter.
3. Why is aluminum added to commercial drain-cleaners?
4. Why is it a good practice to pour boiling water down sink drains occasionally?

Problem 5. What should a good home medicine cabinet contain?

Suggestions for the medicine cabinet. The home medicine cabinet is usually placed in the bathroom and is filled with shaving supplies, toilet articles, and all sorts of odds and ends. It should be arranged neatly and every item properly marked so that there could be no mistake in identifying an article. The cabinet should contain directions for first aid in the home. A valuable pamphlet entitled *The Home Medicine Cabinet* may be obtained by writing to the United States Department of Labor, Washington, D.C.

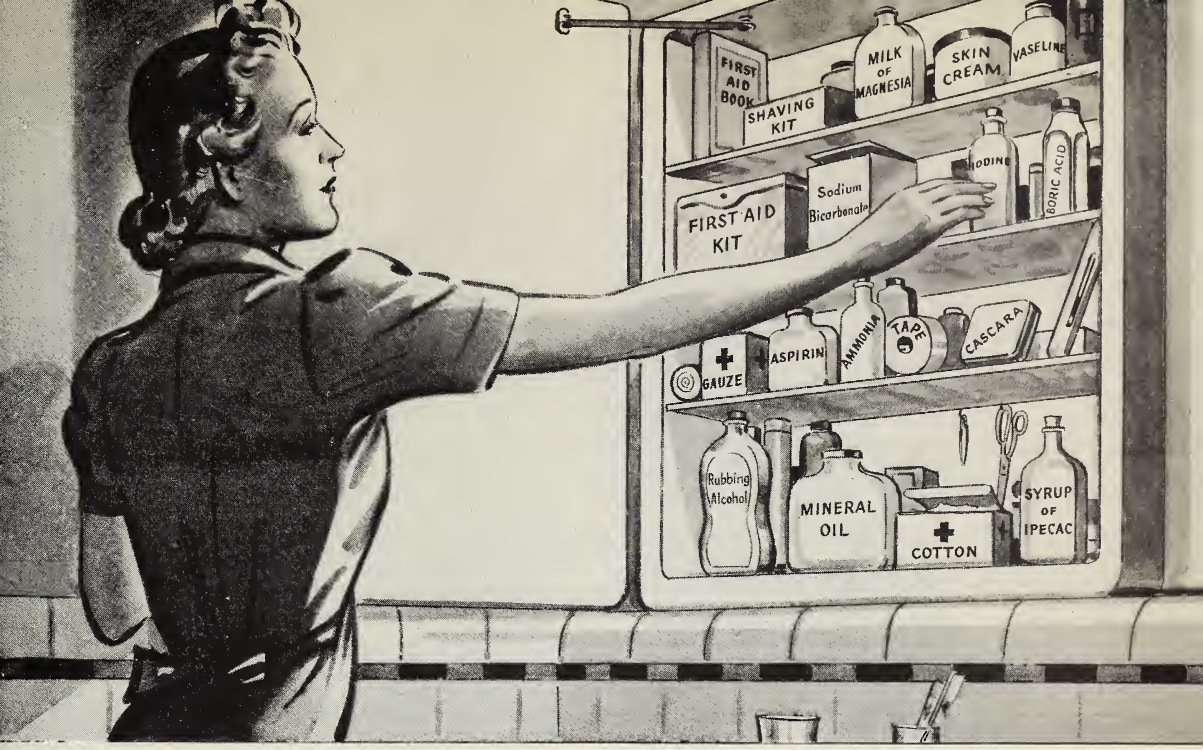
The home medicine cabinet should include the following articles:

1. Antiseptics for cuts and scratches. Tincture of iodine, 1 ounce of a 3½ per cent solution. Rubbing alcohol, 1 pint.
2. Burn preparations. Four ounces of tannic acid powder or picric acid gauze or "Amertan."
3. Pain-reliever. Aspirin or "Empirin."
4. Laxative, such as cascara sagrada, milk of magnesia, or mineral oil.
5. Emetic to produce vomiting. Sirup of ipecac.
6. Stimulant for use in shock or fainting. Aromatic spirit of ammonia, 2 ounces.
7. Sterile bandages and gauze. Various sizes in sterile containers.
8. Absorbent sterile cotton.
9. Adhesive tape.
10. Applicator sticks in a tube.
11. Clinical thermometer.
12. Hot-water bottle.
13. Saturated solution of boric acid.
14. Pair of scissors.
15. Pair of tweezers.
16. Sodium bicarbonate.
17. Medicine-dropper.
18. First-aid book.

The medicine cabinet should be in a location out of reach of the children. All bottles should be well corked and labeled. Empty bottles and long-unused medicines should be discarded.

EXERCISES

1. Give illustrations of how each of the articles contained in a well-equipped medicine cabinet may be used.
2. Explain how a clinical thermometer should be used and taken care of.



A well-stocked home medicine cabinet should contain these materials

3. Needles are sometimes used in removing splinters. Explain how you would disinfect, or sterilize, a needle before using it on a wound.

4. Why should empty bottles and long-unused medicines be disposed of?

Problem 6. How may the home be kept free of rodents and insects?

Learn how to control insects and rodents. A sanitary home is free of insects and rodents. Old houses are very frequently infested with these pests. Only by a study of their habits and persistent application of control measures can they be eliminated. People moving into new houses should take special pains to prevent the entrance of insects and rodents. The United States Department of Agriculture has published a number of bulletins dealing with insect and rodent control. Copies of these bulletins may be had by writing to this department, at Washington, D.C. Local libraries often have copies of these bulletins on file.

Control of insects by temperature. Almost all household insects become inactive at temperatures below 40° F. At temperatures of 10° F and lower most insects die. Houses left unheated during the winter are usually free of insects when opened in the spring. Mattresses, clothing, rugs, upholstered furniture, and similar articles can usually be rid of insects and their eggs by exposing them to ten or more hours of temperatures below 10° F.

High temperatures of 120° F or more will kill all insects and their eggs. A house may be effectively cleared of insect pests in the summer by heating it for three or four hours at a temperature of 130° F. Select a hot calm day in the summer and start the heating plant. A thermometer should be placed near the floor in the coolest part of the house and the temperature raised to 130° F. All closets, boxes, and trunks should be left open to expose their contents to the heat.

The exposure of infested articles to the direct rays of the sun in the summer will also aid in ridding them of insects.

Other methods of control. The eradication of insects by the use of poisonous gases is effective. However, it is dangerous for one not experienced in this method to attempt it. Exterminating firms are located in most large cities. Their services should be secured if this method of eradication is to be applied.

The most effective fumigant is hydrogen cyanide, or hydrocyanic acid gas (HCN). It is a deadly poison and should be used only by competent professional exterminators. Rooms must be carefully sealed and the gas left in them for about twenty-four hours.

Sulfur fumes created by the burning of sulfur in rooms are sometimes used. About three fourths of a pound of sulfur should be burned for each 1000 cubic feet of space. Though sulfur is effective, its bleaching and tarnishing effect on articles in the home must be taken into consideration.

The secret of eradicating *ants* lies in finding their nest and killing the queen and the young. The killing of the workers merely weakens the colony. Sodium fluoride (NaF) powder is an effective poison for ants. It may be purchased at drugstores. It should be dusted around window sills, in corners, along the edges of flooring, and in other places frequented by ants. A sirup for destroying ants may be made by dissolving 1 ounce of tartar emetic, or potassium antimonyl tartrate ($K(SbO)C_4H_4O_6$), in 1 pint of thick sugar sirup. This solution should be placed in shallow dishes where ants will find it.

Bedbugs lay their eggs in cracks of flooring and furniture. They are found in the tufts of mattresses and around bedsprings. Their eggs may often be removed with a vacuum-cleaner tube. Kerosene applied with an atomizer spray or a syringe is effective. It should be injected into every crack and corner of flooring, walls, and furniture. Fumigation with hydrocyanic acid is the most effective method of extermination, but this fumigant must be used under the direction of a specialist who is familiar with its extremely poisonous nature.

Cockroaches are often found around the base of kitchen sinks, in pantries, under cupboards and baseboards, and in basements. Sodium fluoride should be dusted around those areas which are likely to be infested with cockroaches.

Inasmuch as sodium fluoride is a poison, borax ($Na_2B_4O_7 \cdot 10\,H_2O$) mixed with three times its

Opening cans of hydrocyanic acid gas in preparation for fumigating a boat's hold to kill disease-carrying rats. The same kinds of materials and equipment are used in home fumigation

United States Public Health Service

bulk of cocoa powder may be used. Pyrethrum powder, obtained from the flowers of the chrysanthemum, may be used to exterminate cockroaches.

Crickets are most effectively destroyed by the use of pyrethrum powder blown under furniture and sinks and in pantries. The powder smothers the insects as it settles upon them.

Carpet beetles may infest the floor coverings of the home. The underside of these coverings should be inspected regularly for the presence of these insects and moths. A vacuum cleaner run over the underside of a rug will usually remove the eggs. Kerosene should be run into cracks in the floor and around baseboards to kill the insects and their eggs.

Fleas, either from pets or sand, sometimes infest the house and are usually found in the basement. They may be eradicated by scattering one or two pounds of powdered naphthalene ($C_{10}H_8$) or paradichlorobenzene ($C_6H_4Cl_2$) about the floor and closing all doors and windows tightly. The room should be kept warm, as this helps to volatilize some of the powder, and should be kept closed for at least one day. Kerosene may be sprayed about outhouses to rid them of fleas, but extreme caution should be used because of the inflammable nature of kerosene.

Food weevils may infest such dry foods as meal, flour, and cereals. Food containing them should be burned.

Houseflies may be controlled in several ways. Flypaper is effective if correctly placed in the house. A formalin solution made by mixing three teaspoonfuls of 40 per cent formaldehyde ($HCHO$) and a pint of water or milk to which has been added a little sirup or brown sugar may be used as a lethal bait for flies. It should be placed with pieces of bread in a saucer or tin pan on objects out of reach of household pets or children.

Most commercial fly sprays are a mixture of water, white kerosene, and pyrethrum powder or its extract. They are not 100 per cent effective, as many flies revive after a time.

Mosquitoes may become very annoying during the summer months. It has been pointed out that any can or vessel containing water may prove to be the breeding ground of mosquitoes. Water left standing in pools may contain thousands of mosquito larvae.

E. I. Du Pont de Nemours & Co.

Flies are carefully reared in captivity in this "fly farm," a unit of the Du Pont Pest Control Laboratory at Wilmington, Delaware. They are then killed in the course of a scientific study of insecticide chemicals

In regions where mosquitoes are common, the screening of houses should be of fine mesh and tightly fitted. A pyrethrum-kerosene spray may be used to rid a room of the insects. Such a spray mixture may be made by adding one pound of pyrethrum powder to one gallon of white odorless kerosene. The mixture should be allowed to settle and the clear liquid used.

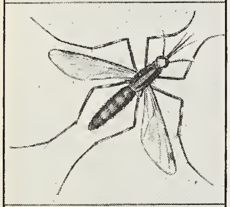
Many fishermen and campers find oil of citronella an effective repellent of mosquitoes. The oil is rubbed on the exposed parts of the body. A mixture of one part oil of citronella and four parts mineral oil or liquid "Vaseline" will last longer, since oil of citronella is volatile.

Moths are common in most households. Moth control was discussed on pages 275–276.

Rats and mice are most effectively removed by the use of the common bait snap trap. Rat poisons containing thallium, arsenic, and other poisonous chemicals are on the market, but such poisons are generally to be avoided because they are dangerous where there are children or pets and also because the poisoned rats or mice may die in the house. It is sometimes asserted that the poisoned animals will go out of doors to die, but they may not be able to get out of doors.

Wood ticks are common in the spring of the year, particularly in mountainous and wooded areas.

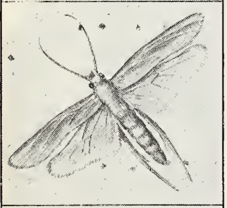
The housefly is a notorious carrier of dangerous diseases. It has been the means of spreading summer diarrhea and typhoid fever. You should make every possible effort to exterminate every fly you find in the house



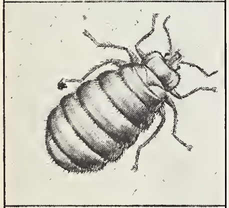
Mosquitoes are not only annoying; they are also dangerous. Malaria and yellow fever, as well as the less well-known but dangerous dengue and filariasis, are transmitted by them. An insect spray should be applied to wipe out these insects

Cockroaches are disagreeable and damaging and may prove dangerous. They may work damage to leather goods, such as furniture, boots, and bookbindings. Although of tropical origin, they have now spread throughout the world. They live best in a warm and moist environment

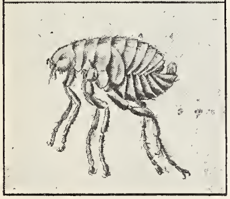
Ants are the most abundant of insects. They damage plant life. Some give painful stings. To the householder, those which nest indoors prove especially troublesome, and their extermination requires persistent attention



The clothes moth damages every year many million dollars' worth of clothing and household furnishings



Among the species of bedbugs there are two which attack man. They feed on blood, and are thus well adapted for the transmission of disease. A thorough attack upon them with insecticide wherever they appear is necessary



Fleas are commonly found on domestic animals. They may, however, get into rugs, furniture, etc. and thence pass to man, causing considerable discomfort with their bites

They may transmit Rocky Mountain spotted fever and tularemia. People visiting or picnicking in areas known to contain these insects should examine their bodies each evening. If a tick has become attached to the body, extreme care should be used in removing its head, which may be embedded in the flesh. A drop of turpentine or benzine may cause the tick to drop from the skin. One should thoroughly disinfect the bite with iodine, making sure that some of it is worked into the wound.

How to protect a house against termites. People have become excessively alarmed over possible termite damage. Termites are not spreading over the country, and they have been in existence for millions of years. They will attack any wood or cellulose material if it is moist, even though it is chemically treated. They establish themselves in a house where lumber is in contact with moist earth, or they may enter through clay tunnels which they can build over shallow masonry walls or through crevices in foundation walls. The clay tunnels are about the size of a lead pencil. The best assurance against termites is good construction so that there is no ground in contact with wood. Where termites have already entered a house, the best means of eradication is to remove the source of dampness. They cannot live where the wood is dry. For this reason, concrete foundations should be extended at least twelve inches above the ground. All wooden steps and porches should be on masonry foundations. Houses without basements should have an 18-inch clearance and should have screened ventilators to provide adequate ventilation. Where it is impossible to reconstruct termite-damaged wood parts and keep the area dry, infestation can be temporarily prevented by soaking the ground with crude orthodichlorobenzene solution.

EXERCISES

1. Make a list of diseases which may be spread by various insects.
2. Make a list of common insects and beside each write a short statement about how to eradicate it.
3. Explain how you would go about eradicating moths from your home.
4. What can each family do to help to reduce flies and mosquitoes in the neighborhood?
5. How do termites damage homes?

A model of a termite colony[1]

PROBLEMS FOR FURTHER STUDY

1. Outline a plan for making a home sanitary.

2. What chemicals are used in your home to make it sanitary? State their composition and their use.

3. What are the compositions of the various brands of rat and rodent poisons sold in your community?

4. How do electric garbage-disposal appliances work? What are their advantages and disadvantages?

5. Make a list of the contents of your home medicine cabinet. What use is made of each item? What is the chemical composition of each medicine?

6. What problems of sanitation are peculiar to mountain or seashore cabins? How is each problem taken care of?

7. How is chlorinated lime used in making outhouses more sanitary?

8. What are the best methods for cleaning rugs, carpets, and upholstered furniture?

9. What are the most acceptable methods to use and what chemistry is involved in the washing of dishes, cotton goods, silk, rayon, and woolen goods?

10. What sanitary measures should be taken when persons in the home are ill?

UNIT EXERCISES

A. On a separate sheet of paper write the word *true* for those statements which are true and the word *false* for those which are false. Rewrite the false statements so that they are true.

1. An alkali is used in making soap.

2. Glycerin is a by-product in the manufacture of soap.

3. Soaps made by treating fats with KOH are firmer than those made by treating fats with NaOH.

4. Sodium sulfate is sometimes added to soap to make it lather more freely.

5. The cleansing power of soaps containing rosin is greater than the cleansing power of those which do not contain it.

6. Washing powder may be used to soften water for laundry purposes.

7. When sodium carbonate is used in laundering, the clothes are made whiter because oxygen is liberated from sodium carbonate.

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[1] Reproduced from Powers, Neuner, Bruner, and Bradley's *Exploring Our World*, Ginn and Company.

8. The washing of clothes with soap is called saponification.

9. Water glass is added to certain soaps to make them float in water.

10. Woolen goods may be washed with soapless soaps, since these soaps contain no alkali.

11. Bluing is added to rinse water in laundering to make white clothes whiter.

12. Soap will react with the minerals in hard water to make the water soft.

13. Bluing is a dye.

14. The best bluing is that which contains iron salts.

15. The principle of water-softening is that of causing the chemicals which make the water hard to be precipitated, or made into insoluble compounds.

16. Soapless soaps are not as good cleaning agents as regular laundry soaps.

17. The bleaching action of sodium hypochlorite is directly due to the chlorine.

18. Sodium hypochlorite may be used to bleach all kinds of cloth materials.

19. A mild soap is probably the best cleanser to use on painted surfaces.

20. Commercial window-cleaners are essentially white odorless kerosene.

21. The manner in which garbage is disposed of in the individual home is of no concern to the neighbors.

22. A garbage receptacle should be emptied at least once a day.

B. On a separate sheet of paper write whatever is necessary to complete each of the following statements correctly. Do not write in this book.

1. Add two words to complete this word equation for the manufacture of soap:

$$\text{Fat} + \text{--(?)--} \longrightarrow \text{soap} + \text{--(?)--}.$$

2. Hard water is usually due to the presence of --(?)-- and --(?)-- sulfates and chlorides in the water.

3. Two chemicals which, when added to water, help to soften it are --(?)-- and --(?)--.

4. Most of the commercial bleaches now being sold are a chemical compound whose formula is --(?)--.

5. A good chemical compound to add to water to be used for cleaning windows is --(?)--.

6. After the shutoff valves in the home water system have been closed and the water drained, any remaining water may be kept from freezing by dissolving --(?)-- in it.

7. A grease trap which is clogged with grease may often be opened with a hot solution of --(?)--.

8. Two chemical substances which are good fumigants are --(?)-- and --(?)--.

9. Ants may usually be controlled in the home by using the chemical compound --(?)--.

10. Commercial fly sprays are usually a solution made by dissolving pyrethrum powder in --(?)--.

REFERENCES FOR FURTHER READING

Berry, Pauline G. *Chemistry Applied to Home and Community.* J. B. Lippincott Company, Philadelphia, 1926.

Carver, T. N., Woolman, M. S., and McGowan, E. G. *Textile Problems for the Consumer.* The Macmillan Company, New York, 1935.

Chenoweth, L. B., and Morrison, W. R. *Community Hygiene.* F. S. Crofts & Co., New York, 1936.

Cobb, Walter Frank. *Everyday First Aid.* D. Appleton-Century Company, Inc., New York, 1937.

Friend, M. R., and Shultz, Hazel. *Clothing.* D. Appleton-Century Company, Inc., New York, 1933.

Johnson, Alva L. *Bacteriology of the Home.* The Manual Arts Press, Peoria, Illinois, 1929.

Osborn, F. A. *Physics of the Home.* McGraw-Hill Book Company, Inc., New York, 1935.

Reich, Edward, and Siegler, C. J. *Consumer Goods.* American Book Company, New York, 1937.

Carbon Disulfide as an Insecticide, Farmers Bulletin No. 799, United States Department of Agriculture.

Cockroaches and Their Control, Leaflet No. 144, United States Department of Agriculture.

The Control of Moths in Upholstered Furniture, Farmers Bulletin No. 1655, United States Department of Agriculture.

Flytraps and Their Operation, Farmers Bulletin No. 734, United States Department of Agriculture.

House Ants, Leaflet No. 147, United States Department of Agriculture.

The House Fly and How to Suppress It, Farmers Bulletin No. 1408, United States Department of Agriculture.

Rat Proofing Buildings and Premises, Farmers Bulletin No. 1638, United States Department of Agriculture.

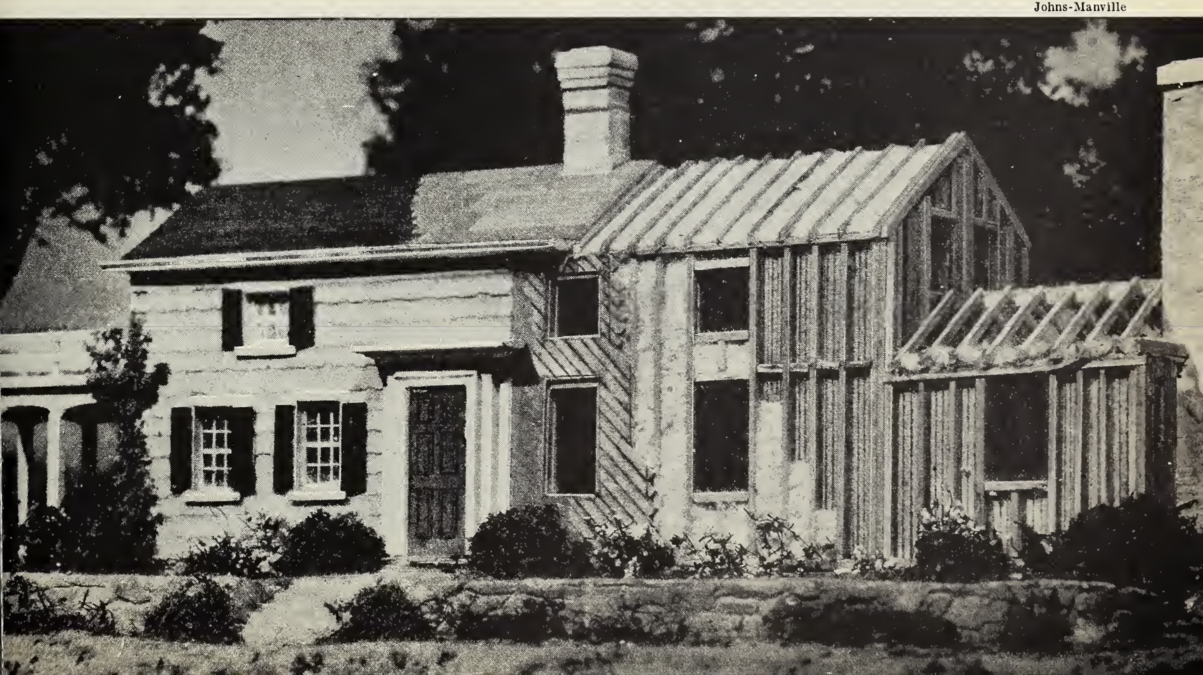
UNIT 26

The Chemistry of Materials Used in Modern Home Construction

The house in which you live is made of an exceedingly complicated mixture of materials, and houses that are being built today are even more complex. In a house you will find almost as many different materials as there are different parts. To discover the chemistry of the many construction materials in a house, it will be necessary to examine the foundation, exterior finish, interior finish, flooring, roofing, framework, and insulation. Any one of these parts may be made of many separate materials or combinations of materials. To know about the qualities and properties of building materials will help you and your parents to maintain your present home or in buying a new one.

Many different kinds of construction may be found in a house. For example, a house which can be heated economically because of excellent insulation may have sagging floors, or a house may have a good kitchen sink but a poor foundation. Moreover, all the materials used in constructing your home may be of high quality, and yet it may be poorly built. Neither good materials and poor workmanship nor good workmanship and poor materials make a desirable house. High quality in workmanship and materials is necessary if lasting satisfaction is to be had from your house.

Modern living in a modern home is a direct result of the application of chemical knowledge. For example, a modern house, with its large amount of window space, is light and airy. Even our basements are light and livable now, whereas formerly they were dark and dingy. This has been possible because of the chemist's contribution of the knowledge of how to make glass cheaply. Chemistry has taught us how to waterproof our basement walls and floors. It has given us the knowledge of how to make the



Johns-Manville

The application of chemistry to the improvement of construction and construction materials has made modern homes more healthful, durable, and livable

pipes which convey water and heat throughout the house and sewage away from the house.

The house of yesterday was hot during the summer and cold during the winter. Now, because of new insulation materials, we can reverse these conditions. A well-built modern house is comfortable in any nook or corner during winter or summer.

In addition, new structural materials are now being used to make houses stronger and more durable. Stone, brick, and wood have been the orthodox materials out of which to build houses, but now we are using man-made steel and concrete. Moreover, synthetic materials are used for walls, floors, and roof coverings. The house of yesterday seems undesirable to us because of the improvements in the materials which we use in the modern house. The house of tomorrow will probably make the house of today also unlivable because of additional applications of chemistry. The accomplishments of the many research laboratories and governmental agencies in the building industry are so extensive that we are rapidly erecting the framework of a new branch of science, known as building science.

PURPOSES TO BE ACHIEVED

1. To discover how chemistry has contributed to the development of materials for modern home construction.

2. To gain information about construction materials so that you and your parents may better know how to build or buy a home.

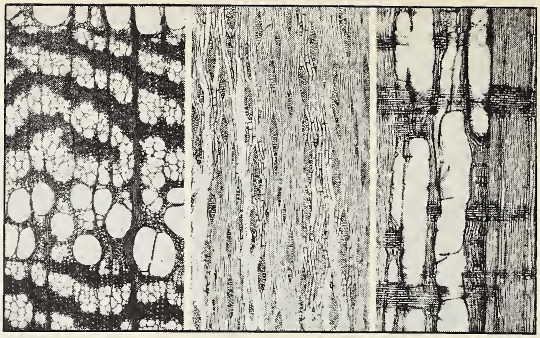
PROBLEMS TO BE SOLVED

1. What are the chemical nature and the methods of manufacture of materials used in the building of our homes?

2. What are the advantages and disadvantages of the different kinds of building materials?

Problem 1. What are the chemical nature and the methods of manufacture of materials used in the building of our homes?

Wood. A safe and healthful house may be built from many kinds of materials. The oldest and also most-used building material is wood. Wood is composed chiefly of cellulose ($(C_6H_{10}O_5)_x$) and a small percentage of minerals. When wood is perfectly dry, about half of its weight is due to carbon, and the other half is due to hydrogen and oxygen in the same proportion as in water. The chemical composition of all woods is approximately the same. The minerals constitute about one part in one hundred by weight. The ashes remaining when wood is burned are made up of the minerals formerly in the wood. Wood is made by the tree of carbon dioxide from the air and of water and minerals from the soil, united in the presence of sunlight with the aid of the catalyst chlorophyll.



A microphotograph showing the cellular nature of wood[1]

Physical nature of wood. Though most woods have the same general chemical composition, the physical structure of the various kinds differs greatly. These physical differences are primarily responsible for the variations in the properties of different woods. All kinds of wood have a cellular structure; that is, wood is composed chiefly of cellulose, which is arranged in elongated tubes, or cells. These cells play a very important part in the life of the tree in that some of them serve to conduct water from the roots to the leaves, some to store away digested food, and some to build up a tough body structure. All the life processes of the tree take place within the cells which make up what we call wood.

Wood has some special advantages as a building material, and many of these are due to its cellular structure. When a nail or screw is driven into wood, the vacant cell cavities allow the cell wall to expand so that the nail or screw can be easily forced into the wood. Therefore two pieces of wood can be easily fastened together, affording endless possibilities of unusual construction. The cell cavities account for more of the volume of wood than is commonly thought. Most of the common wood used for building is composed of empty cell spaces. It is therefore possible to work wood easily and make it into various forms with relatively simple tools. Wood is light when dry because the empty cell spaces are filled with air, not with water. The cell pores act as dead-air spaces, and therefore lumber is a good insulator of heat and sound. All these qualities are particularly desirable in the building of a house.

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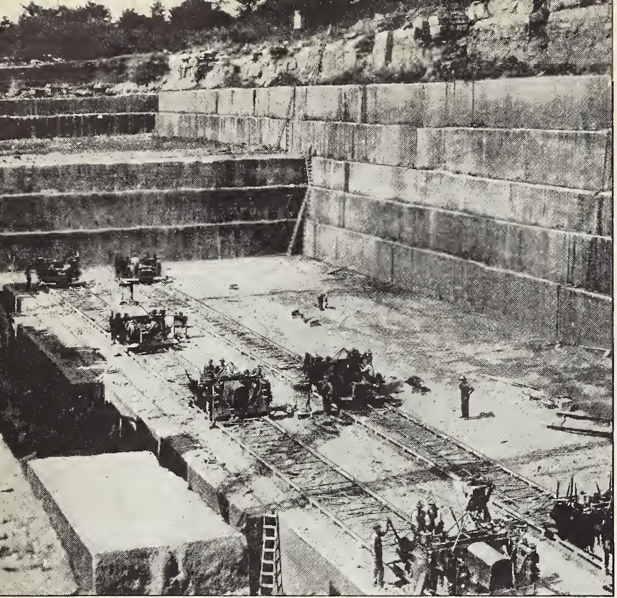
[1] Reproduced from Pool's *Basic Course in Botany*, Ginn and Company.

Kinds of wood. Woods are generally classified according to hardness. For example, we have hardwoods and softwoods. The softwoods are those cut from coniferous and other evergreen trees, whereas the hardwoods are those cut from the broad-leaved and deciduous trees. (Deciduous trees are those from which the leaves fall at the end of the growing period.) However, this classification does not always hold when various woods are examined for hardness. Some of the softwoods are harder than some of the hardwoods, and the reverse of this is also true. The degree of hardness in any wood is due to the degree of the compactness, or closeness, of the cells. This property of hardness, which in building is thought of as the ability to resist denting, scratching, or cutting, is a very important one when wood is considered for building purposes. Hardwoods or hard softwoods are used in flooring and finishing because of their more beautiful grain, whereas much softer woods can be used elsewhere because they are cheaper and more easily worked. The harder woods wear much longer than the softer woods.

Wood for building is obtained from many different trees. The hardwoods most commonly used are those cut from walnut, oak, hickory, hard maple, elm, ash, beech, birch, poplar, and chestnut trees. The softwoods come from such trees as cedar, fir, pine, spruce, and hemlock. Such woods as mahogany, satinwood, and ebony are hard woods and are sometimes used for building, but since they must be imported, they are too expensive for common use.

A deciduous tree and an evergreen tree. What kind of wood is obtained from each of these trees?

United States Forest Service



Indiana Limestone Corporation

Limestone building blocks are obtained from this Indiana quarry

The seasoning of wood. Before wood can be used, it must be dried. The process is known as seasoning. Wood can be air-dried or kiln-dried to evaporate the excess moisture which it contains. Well-seasoned wood will not shrink or warp as much as green wood. Therefore seasoned wood is the only kind which should be used in the building of a home.

The sawing of wood. Wood may be sawed in different ways to bring out its grain and beauty. For most general uses, wood is sawed flat; that is, a log is cut into thin lengthwise slabs. Flooring and some finish lumber is quarter-sawed; that is, the log is quartered, and then each quarter is cut across the growth rings. Such a method yields a much more beautiful grain.

Building stone. Stones and rocks are the oldest building materials known; and because they possess the qualities of strength and durability, they are still used in modern construction.

Natural rock may be classified according to its origin as follows: *igneous* (from Latin *ignis*, "fire") *rock* is that rock which was formed when the earth cooled from the molten state. Granite and basalt are excellent examples of igneous rock. As the earth grew colder, the weathering agencies wind and water and the force exerted by plants in their growth caused these igneous rocks to break down, or disintegrate. From the disintegrated rocks sand (SiO_2), clay ($H_2Al_2(SiO_4)_2 + H_2O$), and other materials were formed.

Sedimentary rock is that rock which was formed much later in the earth's history when disintegrated igneous rock particles, seashells, and mud settled from the water which covered part of the earth. This sediment became cemented together and formed sedimentary rock. Sandstone and limestone are good examples of sedimentary rock.

Metamorphic (from a Greek word meaning "transformation," or "change of form") *rock* is that rock which has been changed from its original form by means of extreme pressure or heat or both these agencies. For example, marble ($CaCO_3$) was once limestone. It was subjected to extreme pressure when folding of the earth's crust took place. The resulting pressure and heat caused the limestone to assume a crystalline structure and become what we call marble. The chemical composition was not altered. Slate is another metamorphic rock.

Building stone must be of such a nature that it can be worked, or fashioned, and, at the same time, it must be durable enough to resist chemical decomposition due to atmospheric agencies. If the stone is to be used for building a home, it must be strong enough to stand heavy pressures without crumbling and must be obtainable close enough to the building site not to be prohibitively expensive. Building stone should have an attractive appearance.

The lasting quality of building stone. The durability of a particular kind of stone depends on its chemical composition, physical structure, the ease with which it absorbs water, and the kind of atmospheric conditions to which it is exposed. Stones are generally tested for endurance by determining the weight of the water absorbed in a given time. The least durable stone will absorb the most water. The following table shows the absorptive power of some stones:

Stone	Per Cent of H_2O Absorbed
Granites	.06 to .15
Marbles	.08 to .16
Limestones	.2 to 5
Sandstones	.41 to 5.48

Absorbed water affects the endurance of rocks or stones because it freezes during cold weather, causing an expansion which weakens and crumbles the rock. If the water contains a dissolved acid, such as sulfuric or carbonic acid, it will bring about rapid decomposition of limestones and marbles. The atmosphere of a large city with much smoke will contain enough sulfuric acid to affect the endurance of these two stones.

Chemical tests of building stones. An interesting test to show the effect of frost on rocks is known as the Barrd test. In conducting this test, small pieces of stone are immersed in a concentrated boiling solution of sodium sulfate, or Glauber's salt ($Na_2SO_4 \cdot 10\,H_2O$), and then they are hung up in the air for three days. The water gradually evaporates, leaving crystals of the salt in the pores of the stones. Small bits and sometimes larger sections of the rock surface will be forced off when the salt crystallizes. The pieces of stone are weighed before and after they are tested. Therefore the amount of disintegration, which is the same as is normally caused by frost, can be calculated. Generally the greater the loss of weight during this experiment, the poorer the quality of the stone.

The presence of a large amount of magnesium or calcium carbonate can be shown by testing stones with a drop or two of sulfuric acid. An intense evolution of carbon dioxide (CO_2) will be given off if there is a large percentage of the carbonate rocks in the sample. The ability of a particular kind of stone to withstand the effects of a smoky atmosphere can be tested by soaking a sample for several days in a 1 per cent solution of sulfuric acid. If the stone contains materials which are likely to be affected by the gases of the atmosphere, the solution will become cloudy.

Although many chemical preparations, such as paint, coal tar, and paraffin, have been applied to external stone or rock surfaces to prevent deterioration, none are acceptable in affording permanent protection to a house.

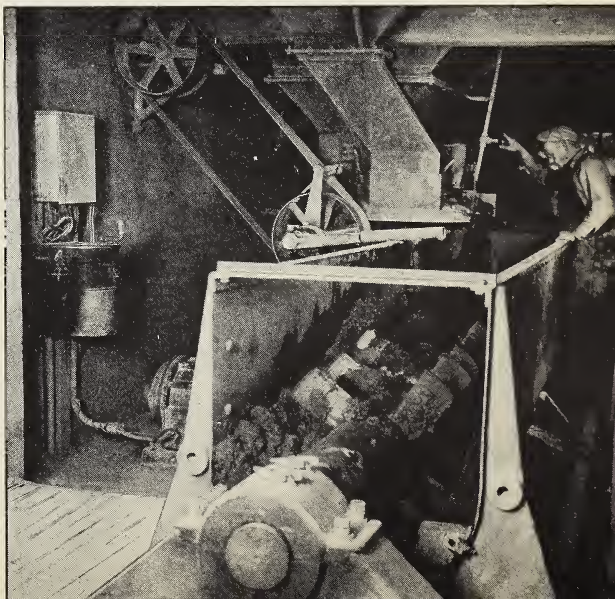
Stonemasonry construction for the walls of a home must of necessity be thick. This sometimes produces a damp coldness in the house, which is objectionable. Good construction by skilled workmen who know how to finish the surface will sometimes eliminate this condition.

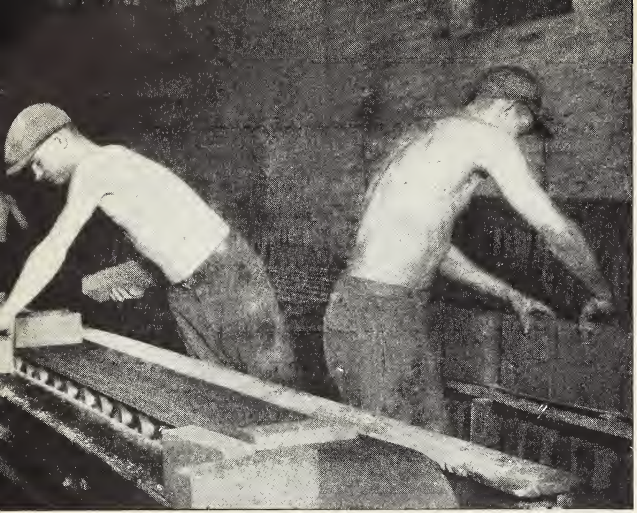
Houses of stone are not generally cheap to build. The cost will depend on the nearness of the building site to the source of the rock and the cost of hiring competent stonemasons. Because of its weight, stone is not acceptable for building purposes where it has to be transported over long distances.

Clay products. Clay has been an important building material since early man first made his home from twigs and daubs of mud. Gradually it was discovered in all civilizations that if clay was baked, it became very hard and more durable. Now we have numerous building materials made from baked clay, namely, bricks, tile, terra cotta, and cement and concrete. You may properly think of brick as being the first man-made building material.

Clay is a mixture of the silicates of sodium, potassium, aluminum, and sometimes magnesium. The mixture may be combined with water of hydration in varying amounts. It is formed from the gradual weathering of such rocks as mica ($KAlSiO_4$) and feldspar ($KAlSi_3O_8$). A mixture of these two minerals constitutes the rock known as granite. When granite disintegrates, owing to the action of moisture and carbon dioxide of the air, the potassium which it contains is removed as potassium carbonate, leaving clay ($H_2Al_2(SiO_4)_2 \cdot H_2O$). When clay is absolutely pure, it is known as kaolin. In this form it is a powder, but when additional water of hydration is added, kaolin becomes plastic and can be easily molded.

This is a pugmill and is used to mix thoroughly the clay materials which go into the making of bricks





Ewing Galloway

Wet, or "green," bricks are stacked in a kiln, in which they will be baked at a temperature of from 1000° to 1600° C

The chemistry of brick manufacture. The clay used in making bricks generally contains lime (CaO) and iron oxide (Fe_2O_3), in addition to hydrogen aluminum silicate. There are three processes by which bricks are made: (1) stiff mud, (2) soft mud, and (3) dry press.

In the stiff-mud process the clay is ground, sifted, and mixed with the proper amount of water to a consistency of bread dough. The mixture then goes to the brick-forming part of the machine, where the stiff mud is forced through a rectangular opening and becomes a column of soft brick. The column is cut into brick lengths by wires.

In the soft-mud process sand and coal are mixed with clay, and water is added to produce a consistency of soft mud. This mixture is placed by hand in individual brick molds. After some of the water has evaporated, the bricks are dumped out of the molds and dried in the open air. Bricks made by this method are known as common soft brick or sand-mold brick.

Dry-press brick is made from almost dry clay by pressing the clay into brick-shaped steel molds.

After the bricks are cut or molded, they are dried for from twenty-four hours to four or five days and then heated, or burned, in a kiln, or furnace, at a temperature of 1000° C to 1600° C. This temperature is just below that of the melting point of clay. The burning process must be carefully controlled because on this, the most important part of brickmaking, depends the strength, durability, and porosity of the bricks. Under the influence of the tremendous heat, chemical actions take place which alter the chemical composition of the clay. The firing lasts from eight to twelve days. There are many kinds of brick, but those in most common use are known as common brick, face brick, and firebrick. Common brick does not have to be heated to as high a temperature as face brick or firebrick. Since all the silicates do not fuse at the lower temperature, common brick is fairly porous and will absorb water, whereas face brick is said to be water-repellent, by which is meant that face brick does not absorb as much water as common brick. Glazed face bricks are the least water-absorbent of all the kinds of bricks. Firebricks are used for lining fireplaces and furnaces and must be especially heat-resistant. They are made by using clay that has in it very little material that fuses at low temperatures, such as calcium silicate.

Selecting brick. When bricks are bought, two qualities should be checked—their water-absorptive power and their tendency to effloresce. The infiltration of moisture through a brick wall is a serious problem in some climates. This condition may be due to the mortar used in laying the bricks or to improper construction and not to the bricks themselves. Efflorescence is the result of the evaporation of water coming from the inside of the brick and carrying with it soluble salts. The white deposit on the surface of such bricks is made up of the salts which have been carried from within the brick. Good-quality bricks do not effloresce.

Good bricks can be judged somewhat by their appearance. Before buying bricks, however, it should be determined that they conform to the standards set by the American Society for Testing Materials. A brick contractor can be required to meet the specifications set up by this testing agency. When a good brick is struck a sharp blow with a hammer, it rings with musical clearness. Good bricks do not crumble easily, and they break evenly when struck a sharp blow with a trowel.

Tiles. Tiles are made in much the same way and from the same materials as bricks except that they are made in a variety of shapes. The use of tile in building serves many purposes. Solid tiles are used mostly for roof covering and floor paving. Hollow tile is used in the construction of fireproof and soundproof walls, floors, and partitions. Where hollow tile is used in exterior-wall construction, it is generally covered with stucco. Hollow tile is also widely used for making drains and sewer pipes. Tiles for bathroom and kitchen floors and walls are highly glazed by dipping the unburned tiles in a mixture of white sand and various metallic oxides. The tiles are then baked or burned, which fuses the glaze material into a glasslike surface coating.

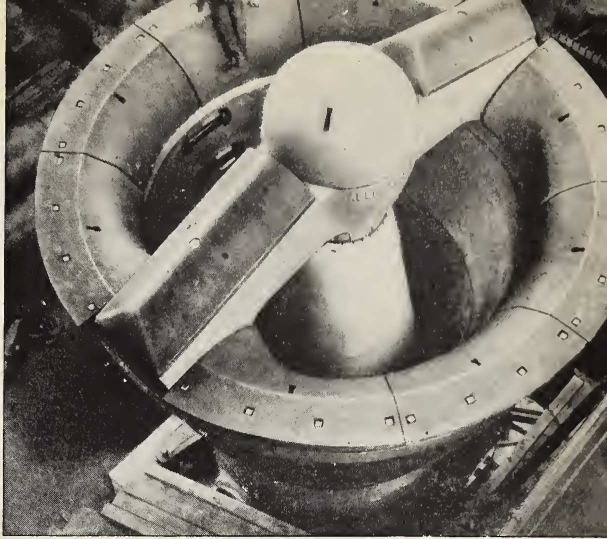
Hollow tile for building main load-bearing walls of homes or larger buildings is being discontinued in the earthquake areas, because the hollow centers make it naturally weak. Hollow tile is a very good non-water-absorbing building material, but moisture sometimes does seep through the mortar joints.

Terra cotta. This term is applied to ornamental building materials made from clay. Plaster casts are made for the pieces of terra cotta needed. Then the proper mixture of clay and fusible minerals is pressed into the mold. This is a manual operation and consists of pressing the wet clay into all parts of the mold. After the clay has dried, the mold is removed, the surfaces are sprayed with the proper-colored ceramic mixtures, and the piece is ready to be fired. Terra cotta made in this way is permanent and gives lasting beauty to the trimming of homes and other buildings.

Cement and concrete. Many persons are confused by these two terms and think that they refer to the same material. Cement is any mixture of lime (CaO) or limestone ($CaCO_3$) and clay ($H_2Al_2(SiO_4)_2 \cdot H_2O$) which has been heated very hot and ground into a fine powder. Cement is a mortar which will harden in water as well as in air. Concrete may be thought of as artificial, or man-made, rock. It consists of cement, rocks or gravel, sand, and water. Cement is the binding agent in concrete.

Terra cotta makes an attractive facing for less attractive surfaces in buildings

Ewing Galloway



Allis-Chalmers Company

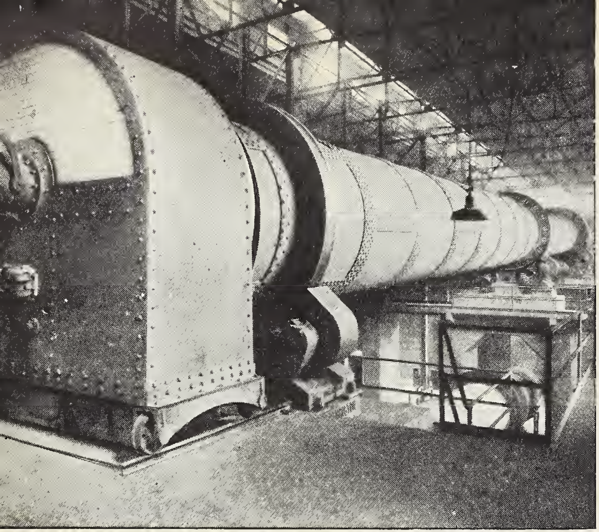
Giant crushers such as those shown here are used to grind rock into a fine powder preparatory to making cement

Portland cement is made by mixing and heating together limestone and clay in exact proportions. The following is an equation for the process:

$$\overset{\text{limestone}}{8\,CaCO_3} + \overset{\text{clay}}{3\,Al_2O_3 \cdot 2\,SiO_2} + \text{heat} \longrightarrow \overbrace{3\,CaO \cdot Al_2O_3 + 3\,CaO \cdot SiO_2 + CaO \cdot SiO_2}^{\text{cement}} + SiO_2 + 8\,CO_2$$

Cement is similar to glass in that it is a mixture of silicates. The hardening, or setting, of cement is not clearly understood. However, most scientists agree that the setting is due to the formation of crystals through the union of the silicates with water and carbon dioxide.

Concrete has one significant advantage over other building materials in that it can be shaped into any desired form by pouring it into molds which may be removed when the concrete sets. It is durable, even improving with age if properly made, and can stand pressures of more than 7000 pounds per square



Lone Star Cement Corporation

Cement is made in large rotary kilns. The intense heat within these kilns brings about a chemical change and almost complete dehydration of the mixture, with the formation of hard clinkers. These clinkers are next ground to a fine powder in steel-ball mills to form cement

inch without crumbling. For foundations and walls, concrete is made by mixing one part of cement with four to seven parts of sand, gravel, or crushed rock. For finishing a surface, such as that of a sidewalk, a richer mixture of one part of concrete to two parts of fine sand is used.

A good quality of cement can generally be purchased by demanding Portland cement.

Precast masonry units may be made from cement. Such units are known as cement blocks, cinder blocks, and preformed concrete slabs. Cement blocks have been found satisfactory when used above the ground, because of their high insulating value, durability, and ability to hold nails. Cinder blocks make a good framework which can be finished with brick or stucco.

All-concrete one-piece houses have been made, but it is expensive to produce them in variety, since entirely new forms are needed each time a different house is built. This makes the houses too costly to compete with natural building materials. Much experimentation is now taking place to determine new and cheaper applications of concrete in home construction.

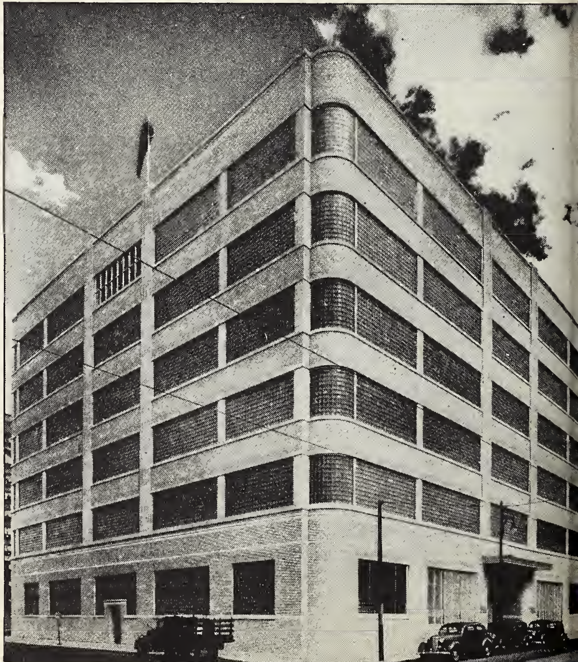
Glass as a building material. The latest and most interesting of modern building materials are glass bricks. They are strong enough to be used in any type of heavy wall or door construction. Each glass brick, or block, is made from two glass boxes sealed together to form a hollow block. Air is partially withdrawn during manufacture, thus ensuring better insulating qualities. Though glass bricks cannot be seen through, they do admit a soft diffused light which is very pleasant. They possess the desirable qualities of being fireproof and of deadening sound, and they have an attractive appearance. They do not need to be painted and will last indefinitely.

Window glass of pure quartz, which will admit the ultraviolet rays of sunlight, is now being made cheaply enough for common use.

Mortar, plaster, and stucco. *Mortar* is the term applied to the binding material used in masonry construction. Some kind of mortar is necessary to make masonry walls solid, moistureproof, and weather-resistant. It must have sufficient strength to resist the heavy loads of the walls. A binding agent which meets these requirements is made by mixing cement, quicklime, and sand, or a simpler one can be made with sand and lime. For underground masonry, such as foundations where bricks or concrete blocks are used, a mortar of cement and sand is considered best; but for work aboveground, lime replaces a part of the cement. Ready-mixed

A windowless office building in which large panels of "Insulux" glass block make up a greater part of the walls

Owens-Illinois Glass Company



Ewing Galloway

What are the purposes of mortar in masonry construction?

mortars for any purpose can be obtained, but they are more expensive than the unmixed ingredients; when the ingredients can be properly mixed on the job, it is unnecessary to buy the ready-mixed type.

Mixtures of Mortar

Ingredients	For Underground Masonry	For Aboveground Masonry	
	Best Mixture	*Best Mixture*	*Cheaper Mixture*
Lime (CaO) Sand Cement	 3 parts 1 part	1 part 3 parts 1 part	1 part 3 parts

Plaster for the surfacing of the interior walls of a house is made in a way similar to that in which mortar is made except that hair or wood fiber is added to make it more adhesive. Plaster of Paris ($(CaSO_4)_2 \cdot H_2O$) is also added to accelerate drying.

Plaster of Paris is made by heating the mineral gypsum ($CaSO_4 \cdot 2\,H_2O$) until it loses three quarters of its water of crystallization:

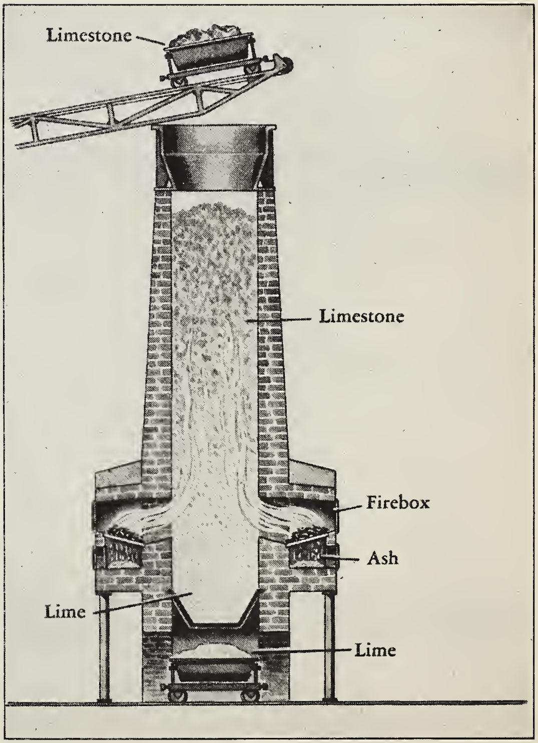
$$2\,CaSO_4 \cdot 2\,H_2O + \text{heat} \longrightarrow (CaSO_4)_2 \cdot H_2O + 3\,H_2O$$

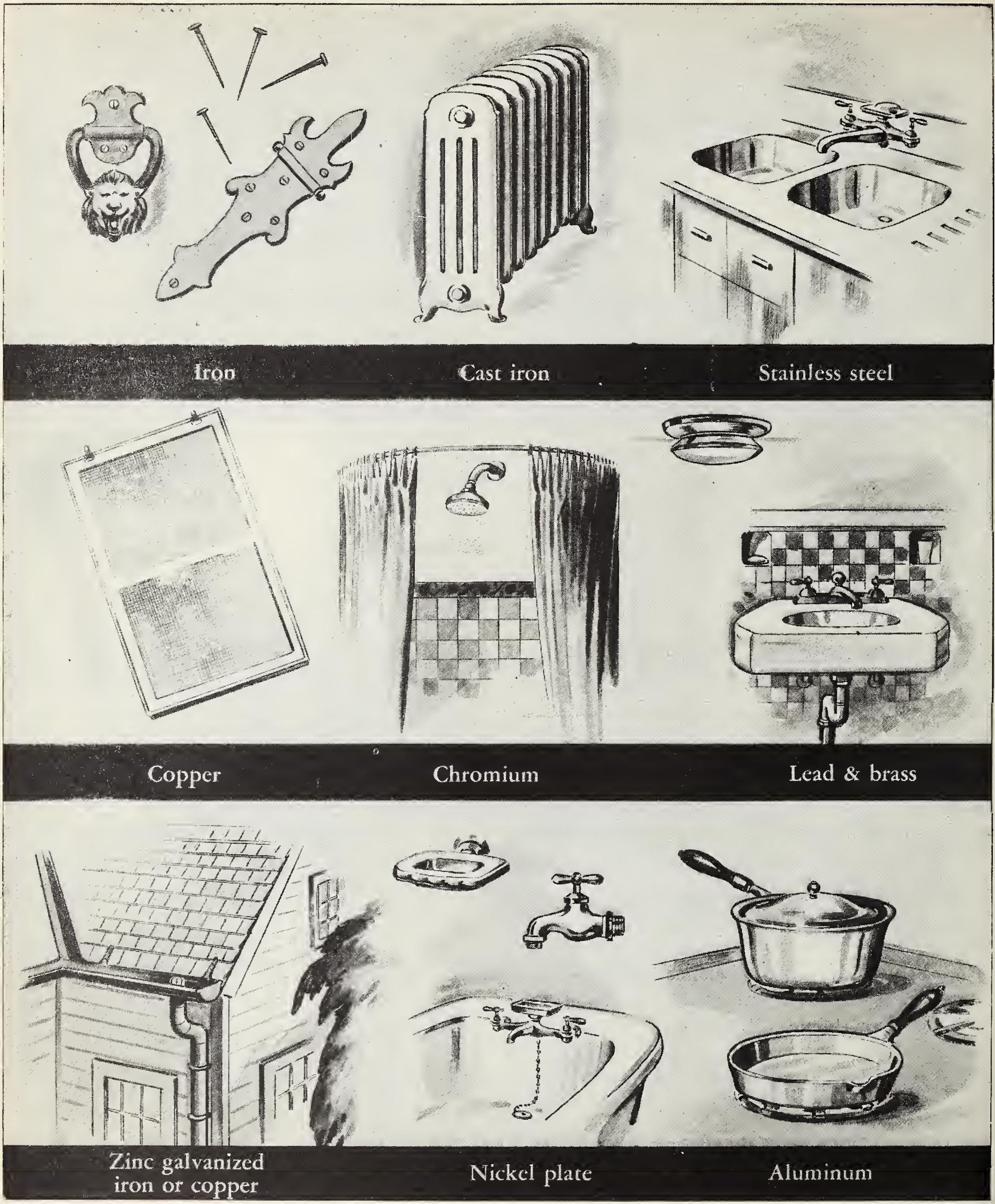
Plaster of Paris is used in hard-surfacing plaster walls. It is also used for molding casts and statuary.

Stucco is a plaster made for outside walls. The ingredients from which stucco is made are sand, lime, cement, and pigments. Mortars and plasters harden, or set, because of three actions: (1) The water in the mixture is evaporated. (2) If cement or plaster of Paris is present, some of the water will be absorbed chemically to form water of crystallization. The equation for the reaction is $CaSO_4 \cdot H_2O + H_2O \longrightarrow CaSO_4 \cdot 2\,H_2O$. (3) The carbon dioxide of the air is gradually united with the calcium hydroxide to form limestone, as shown in this equation: $Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O$.

Metals used in house construction. Many different metals and alloys are used in building a modern house. For example, we find steel used in making nails, bolts, hinges, screws, and locks. Gutters and downspouts are made of galvanized iron (iron coated with zinc). Bronze, an alloy of copper and tin, is used for doorknobs, locks, and hinges. Cast iron (impure iron), lead, copper, and brass are used in plumbing pipes and traps. The heating system is usually made of cast iron, steel, or sheet metal. Plumbing fixtures may be nickel-plated or chromium-plated or iron.

A vertical section of a limekiln





Metals commonly found in the home and some of their uses. Can you think of some other uses of metals in the home?

Ewing Galloway

The erection of a prefabricated house. Four carpenters, in a day and a half, can assemble and erect the units of a complete two-story two-family house. Two additional men, in one day, will lay floor finishings on the first and second floors. Interior wood trim will then be placed by one man in two days

Factory-made houses. Prefabricated houses which are made of steel are now being manufactured. The pieces are molded at the factory and assembled at the location of the house. Such houses may be built, or assembled, very quickly. In Pittsburgh, Pennsylvania, six workmen recently erected a five-room house of prefabricated steel in six days.

Prefabricated houses are also being made of plywood. The wood for exterior and interior surfaces is made by gluing together strips of plywood so that the grains of the sheets, or plies, run crosswise. A synthetic resin adhesive is used. Plywood has not always been satisfactory, because the glues formerly used were not able to resist weathering. However, the new resin type of glue is now being used, and pieces of plywood glued with the hot-pressed resin glues are able to withstand weathering indefinitely. The plies do not separate.

The walls in prefabricated houses are much thinner than those made of masonry or wood; but the space within the wall panels is filled with rock-wool insulation, and this construction makes a house warmer than ordinary construction. Such houses are also fire-resistant, since rock-wool insulation is used also between floor and roof panels. The idea of prefabrication has much to offer in the reduction of costs and the improvement of construction materials, but prefabricated houses must yet stand the test of time.

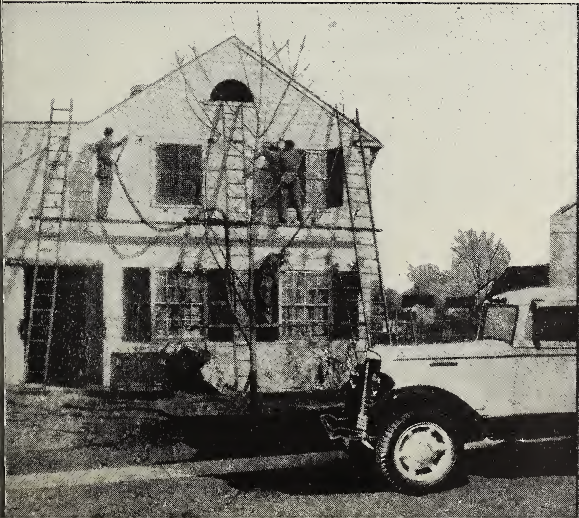
Insulating materials. In the average house the heat loss occurs as follows: (1) About one fourth of the heat escapes through cracks and when doors and windows are opened. (2) One fourth is lost through closed windows. (3) One half escapes directly through roof and walls.

The insulation of a house makes it more economical to heat. Twenty-five per cent or more of the heat bill can be saved by proper insulation. More-

Blowing rock-wool insulation into the walls of a house through holes cut through the outside walls between the studs. When the installation is completed, the sheathing cutouts are replaced and the shingles refastened

In many homes the attic space is valueless; therefore the insulation is blown between the open floor joists. The hose is brought into the house through an upstairs window and then into the attic. The insulation used here is rock wool

Johns-Manville



Johns-Manville

Installing felt bats between the studs of a new home. The flaps along the edges of the bats are nailed to the studs to ensure permanent protection.

over, the insulated house is much easier to heat comfortably and is cooler in the summer.

A substance which is a poor conductor of heat is a good insulating material. Therefore metals are poor insulators, but glass, asbestos, wood, minerals, paper, and air are good insulators. A small dead-air space (that is, a space in which air is not circulating) is the best insulator known. You may have thought that, since the usual house is made of nonconductors of heat, it does not need to be insulated further. Careful examination of the construction will disclose that this is not true. For example, the ceiling that forms the floor of the attic has the thickness only of one lath and a layer of plaster. Moreover, the roof is thin, being separated from the outside by a thin layer of wood. On the other hand, the wall construction of a frame house is double, leaving a dead-air space, which is a good insulating material. Masonry walls are not double, but their greater thickness provides some insulation. For these reasons, insulation, except in the prefabricated houses, is generally applied in the ceiling that forms the floor of the attic and in the roof.

Insulating materials can be divided into the following classes: (1) loose materials which can be poured or blown between ceiling joists or wall studs; (2) the matlike materials; (3) fibrous wallboard; (4) thin sheets of metal.

Loose fillers. This type of insulation is the kind most commonly used. It is especially adaptable to older houses which were built without insulation. Of these materials rock wool is the best because it has high insulating value and is fireproof and verminproof. It is made by heating feldspar rock to the molten state and then blowing live steam into it, which causes the liquid mineral to cool into a light, fluffy mass. In this form it is either blown or lightly packed into the spaces between ceiling joists or wall studs.

Sawdust is a cheap insulator of this type. Its disadvantages are that it is a fire hazard, it is not verminproof, and a greater thickness is required to produce the same insulation as results when rock wool is used.

Ground mica, cork, and tanbark, a by-product of the tanning industry, are also used but are generally more expensive.

All the foregoing materials are poor conductors of heat and are good insulators, mainly because there are millions of small air pockets between the particles.

Matlike insulation materials. Layers of material such as asbestos or chemically treated cellulose are made into mats of the same width as the spaces between joists or wall studs. When these mats are properly placed in all places where heat may be lost, they serve the purpose of insulation very well.

Wallboard as an insulator. Wallboard is made of compressed paper, and it is fairly good as an insulator because paper is a poor conductor of heat. Wallboard may be made also from wood pulp, straw, cornstalks, and cork. These kinds of wallboard are somewhat more efficient than the board made of paper because they contain more air spaces. This type of insulation is most effectively applied when a house is being built. Gypsum is often added as a filler to give wallboard firmness.

Thin sheets of metal as insulation. Some permanently bright metal, such as sheet aluminum, is sometimes tacked under the rafters, over ceiling joists, or on the wall studs as a house is being constructed. Such material insulates because of the reflection of heat and light waves.

Weather stripping. If each window and door in the home is fitted with tight-fitting, grooved metal strips, about 20 per cent of the heat loss will be saved. The metal for this purpose may be a copper alloy or galvanized iron.

Calking materials. These substances are composed of a very slow-hardening plastic which is made from nondrying oils and fillers like fuller's earth or kaolin. When calking compound is forced into the cracks between the masonry and doors and windows, it seals these openings and prevents loss of heat, circulation of air, and water leakage. It is inexpensive and is easy to apply. Therefore every home should be calked.

Miscellaneous materials. Materials for roofing. There are many different roofing materials available for the modern home. Some of them are shingles made from cedarwood, asbestos, or asphalt; others are slate, copper, tin, tile made from clay, asphalt rolls made by pressing thick paper with asphalt, and galvanized iron made from iron by coating it with a layer of zinc.

Screens. Screens may be woven from wire made of galvanized iron, of iron with baked-on enamel and coated with lacquer, of copper, or of aluminum.

Waterproofing substances. To waterproof a wall is to seal its pores on the outside with some material which is insoluble in water. Waterproofing materials are made by dissolving some wax or fatty oil in naphtha. They are applied as paint. The underground waterproofing of a concrete wall consists in applying asphalt paint to the outside of the wall.

EXERCISES

1. Describe the various applications of chemistry to construction materials.

2. What is the composition of wood?

3. How does the physical nature of wood influence its use as a building material?

4. What are the physical qualities of wood which make it suitable for use as a building material?

5. List and describe the kinds of wood.

6. What are the properties of the different kinds of rock used for building purposes?

7. How do the different building stones vary in lasting quality?

8. Describe the chemical tests which may be applied to building stone.

9. What is clay?

10. Describe the methods of making bricks.

11. What changes occur in bricks when they are fired?

12. What is efflorescence?

13. How is cement made?

14. What is the difference between cement and concrete?

15. List the properties of concrete.

16. How is mortar made? How does it differ from cement?

17. What purpose does gypsum serve in the plastering of walls?

18. How is stucco made?

19. Explain the chemical reactions involved in the drying of plaster.

20. What metals are used in house construction?

21. How is plywood made? What qualities does it possess which make it a good building material?

22. How is heat lost in the average home?

23. Why should a house be insulated?

24. What materials may be used for insulating a home?

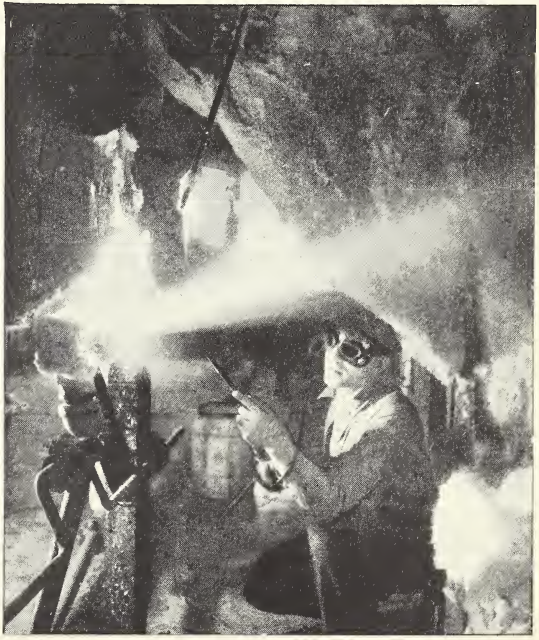
25. Describe the various materials which may be used to insulate a home. Which ones are best?

26. What is calking compound?

27. What is the composition of waterproofing substances?

Man-made volcano. Steam, under 125-pound pressure, hitting a thin stream of molten rock and spinning it into rock wool. Note the fluffy, woollike fibres in the lower right-hand corner. This is the way home insulation is made

Johns-Manville



Comparison of Building Materials for the Exterior of Homes

Interpretation of Table

Rating of 1 indicates
A = Lowest initial cost
B = Most permanent
C = Best appearance
D = Best insulator
E = Least maintenance cost
F = Best resale value

Rating of 5 indicates
A = Highest initial cost
B = Least permanent
C = Poorest appearance
D = Poorest insulator
E = Highest maintenance cost
F = Lowest resale value

Kind of Building Material	A. Initial Cost[1]	B. Permanence	C. Appearance	D. Insulation	E. Cost of Maintenance	F. Resale Value
Wood						
Drop siding	1	4	2 (if kept well painted)	1 (if walls are insulated; otherwise 2)	4	3
Bevel siding	1 +	4			4	3
Bevel siding and plasterboard	2 −	4			4	3
Brick (solid)	2 +	1 +	1	2	1	1
Brick veneer on wood	2	3	2	2	3	2–3
Brick veneer on hollow tile	2 +	2	1	1	1	1–2
Stucco on wood	1 +	5	2	3–4	5	5
Stucco on hollow tile	3	3	2	2–3	3	3
Concrete	3 +	2	3	3	2	3
Natural building stone	4–5	1 +	1	2	1	2
Asbestos shingles	4	2	2	1–2	1	2
Plywood for prefabricated house	3–4	Not yet tested over periods of time	3–4 (severity and sameness detract)	1 (if insulated)	3	4
Steel for prefabricated house	3–4	Thought to be about 2	3–4	1	3	4
Adobe	1	2–3	3–4	1–2	2–3	4–5

[1] Nearness to the place of manufacture or availability of the material will affect the cost.

***Problem 2.* What are the advantages and disadvantages of the different kinds of building materials?**

The selection of building materials depends on many factors. There is a great variety of building materials which are used in home construction. The selection of these materials for specific uses depends on a number of different factors. Some of the most important of these factors are initial cost, permanence, appearance, insulation value, cost of maintenance, and effect on resale value. In the table above an attempt is made to rate some of the commonly used construction materials.

Selecting roofing materials. The consumer has a wide variety of materials from which to select when planning the roof for his house. A comparison of the types of roofing most commonly used is shown in the following table:

Rating of Various Kinds of Roofing Materials

Kind of Roofing	Cost to Lay per Square Foot	Anticipated Life	Insulating Quality	Fire Resistance	Appearance
Shingles (wood)	$.10–$.16	20–40 years if painted	Good	Poor	Good
Tile	.40–1.40	Life of house	Poor	Excellent	Excellent
Slate	.20– .80	Life of house	Poor	Excellent	Good
Tin	.25– .35	20–40 years if painted	Very poor	Excellent	Medium
Asbestos shingles	.16– .35	30–50 years	Good	Excellent	Good
Copper	.80– .90	Life of house	Poor	Excellent	Medium
Asphalt roll	.03– .05	5–15 years	Poor	Poor	Poor
Asphalt shingles	.08– .18	10–15 years	Poor	Fair	Medium to good

EXERCISES

1. What are the advantages of the different kinds of building materials?
2. What are the disadvantages of the different kinds of building materials?
3. What roofing material would you select for your home? Why?
4. What is the poorest type of roofing material? Why?

PROBLEMS FOR FURTHER STUDY

1. How does a geologist explain the formation in the earth of the different kinds of rock?
2. How may sewage lines be constructed to prevent the lines from being damaged by tree roots?
3. What is the cost of building a five-room house in your community with each of several building materials?
4. What is the difference between first-class construction and low-cost construction?
5. What is meant by rammed-earth construction? How expensive and durable is it?
6. What is the relationship between our housing shortage and the average yearly income of the workingman in the United States?
7. Will the prefabricated-house industry provide the stimulus to business which was given by automobile-manufacturing?
8. How are plumbing fixtures made?
9. What is the relationship between modern styles in architecture and modern science?
10. What kind of wood is used in furniture construction?
11. How are brick and tiles glazed with salt?
12. How are the beautiful colors of tile obtained?

UNIT EXERCISES

Some of the statements which follow are true, and some are false. On a separate sheet of paper write the word *true* for those which are true and the word *false* for those which are false. Do nothing for those about which you are doubtful. Rewrite the false statements so that they are true.

1. Chemistry is seldom applied in the making of construction materials.
2. The application of the knowledge of chemistry to building materials has made the modern home cooler.
3. The oldest building material is wood.
4. Wood is a difficult building material to use because it is hard to make it into various forms.
5. Some hardwoods are softer than some softwoods.
6. Pine is a hardwood.
7. Walnut is a hardwood.
8. Wood may be kiln-dried to remove excessive water.
9. Sandstone is a metamorphic rock.
10. Marble is a sedimentary rock.
11. Igneous rock was formed when the earth cooled.
12. The presence of $CaCO_3$ in building stone may be shown by testing the stone with a drop of sodium hydroxide.
13. Clay is a mixture of carbonates.
14. Clay contains water of hydration.
15. Bricks are "burned" at a temperature of 5000° C.
16. Bricks of good quality do not effloresce.
17. Terra cotta is made from clay.
18. Cement is made from limestone and clay.
19. Glass is a mixture of silicates.
20. Portland cement is a poor-quality cement.
21. Concrete and cement are the same in composition.
22. Window glass will admit the ultraviolet rays of sunlight.
23. Glass bricks will last indefinitely.
24. Mortar contains silicon dioxide.
25. Plaster contains some $CaSO_4 \cdot H_2O$.
26. When plaster hardens, limestone is formed.
27. $Ca(OH)_2 + H_2O \longrightarrow CaCO_3 + CO_2$.
28. Prefabricated houses may be made from plywood.
29. Plywood is made by gluing together several thin plies of wood.
30. Prefabricated homes may be completely built in a week's time.
31. A substance which is a good conductor of heat is a good insulating material.
32. A large dead-air space is just as good an insulating medium as many small dead-air spaces.
33. Sawdust is a cheap insulating material.
34. Rock wool is a man-made material.
35. A bright metal, such as sheet aluminum, is a good insulating material.
36. Wallboard may be made from cornstalks.
37. Rock wool is the best insulating material.
38. Stucco on wood makes an excellent exterior building material.
39. Solid brick construction is the least durable.
40. Shingles have poor insulating value.

REFERENCES FOR FURTHER READING

Betts, H. S., and Helphenstine, R. K., Jr. *How Lumber Is Graded.* United States Department of Agriculture Circular No. 64. May be obtained for 10 cents from the Superintendent of Documents, Washington, D.C.

Giese, Henry. *A Practical Course in Concrete.* Portland Cement Association, 33 West Grand Avenue, Chicago.

Hausrath, Alfred H., and Harme, John H. *Consumer Science.* The Macmillan Company, New York, 1937.

Lea, F. M., and Desch, C. H. *The Chemistry of Concrete and Cement.* Longmans, Green & Co., New York, 1935.

Matthews, Mary Lockwood. *The House and Its Care.* Little, Brown and Company, Boston, 1937.

Whitman, Roger B. *First Aid for the Ailing House.* McGraw-Hill Book Company, Inc., New York, 1934.

Comparative Durability of Shingles and Shingle Nails, Pennsylvania State College Bulletin, State College, Pa.

Consumers Research Bulletin, Vol. 5 (new series), Nos. 3, 5, 7, and 8. Consumers Research, Inc., Washington, New Jersey, 1938 and 1939.

Dampness in Masonry Walls above Grade, Letter Circular C514, Bureau of Standards, Washington, D.C. Free.

Experiments on Exterior Water Proofing Material for Masonry, Bureau of Standards, Washington, D.C.

Light Frame House Construction, Bulletin 145, Federal Board for Vocational Education. Obtained for 40 cents from the Superintendent of Documents, Washington, D.C.

Prefabricated House System under Development, United States Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, Wisconsin, 1937.

Recent Developments in Dwelling Construction, Federal Housing Administration Bulletin. May be obtained for 5 cents from the Superintendent of Documents, Washington, D.C.

Recent Progress on Housing Research at the Forest Products Laboratory, United States Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, Wisconsin, 1938.

Recommended Minimum Requirements for Small Dwelling Construction, Building and Housing Publication No. 18. May be obtained for 10 cents from the Superintendent of Documents, Washington, D.C.

Security for Home and Loan, Durable Woods Institute Bulletin, 155 East 44th Street, New York.

Selection of Lumber for Farm and Home Building, Farmers Bulletin No. 1756, Department of Agriculture, Washington, D.C., 1936. Free.

Termites in Buildings, Leaflet No. 101, United States Department of Agriculture, Washington, D.C.

Use and Abuse of Wood in House Construction, Miscellaneous Publication No. 358, United States Department of Agriculture, Forest Service, Washington, D. C. 10 cents.

Wood Handbook, United States Department of Agriculture, Washington, D.C. 25 cents.

UNIT 27

The Chemistry of Home Decorations

Most of us spend a great deal of time in the home. It is a place that most of us enjoy and refer to with a great deal of pride. We are continually striving to make our homes more cheerful and attractive. Science has done much to make our homes more enjoyable places in which to live.

Paints, varnishes, and lacquers have added more to the attractiveness and cheerfulness of our homes than most people realize. Undoubtedly you have seen homes that have had no paint applied to the exterior walls. After a few years the wood becomes unsightly. This same condition would exist in the interior of a house if no paint were used.

The paints of fifty years ago were much less durable than those which are being used today. This is due mostly to the chemist's work in producing and discovering new and more lasting colors. White paint was once used only by those who could afford to paint yearly because its whiteness began to discolor in a very few months. Today white paints are especially prepared to withstand weathering and chemical action. It is not uncommon for a house painted with white paint to have a presentable appearance when three or four years have passed since it was painted last.

The colors used in the paints of the past were usually drab, and the variety of colors was very limited. Today we have paints whose colors are more beautiful than the colors produced in nature. A wide range of colors in paints, from deep tones to beautiful pastels, is now available, and the same range is available in wallpapers, so that any color combination in decorating is possible.

PURPOSES TO BE ACHIEVED

1. To learn the principles involved in successful and artistic decoration.
2. To discover the best uses of decorative materials.
3. To determine the relative merits of various decorative materials.
4. To learn how to select the best decorative materials.
5. To realize the importance of harmony and taste in home decorations.

PROBLEMS TO BE SOLVED

1. Why should decorative materials be used in the home?

A home which is painted regularly retains its attractive appearance and withstands weathering

Ewing Galloway

2. What are paints, enamels, varnishes, lacquers, and other decorative materials composed of, and how are they made?

3. How may home-decorating be done successfully?

4. What factors should be taken into consideration in purchasing decorative materials?

Problem 1. Why should decorative materials be used in the home?

What are decorative materials? The term *decorative materials* in this unit is used to refer to paints, enamels, lacquers, varnishes, stains, and wallpaper. These decorative materials are used in the home for the following reasons: (1) protection and preservation, (2) appearance, and (3) sanitation.

Protection and preservation. Any materials used in constructing or furnishing a home will decay or corrode if exposed to the air without protection. Decay or rusting is usually caused by oxygen, though it may be hastened by moisture, gases, and certain organisms usually found in the air.

When paint or any other related product is placed upon wood, iron, or other materials, it seals the pores, so that the gases and organisms which cause destruction cannot penetrate the material. Thus decorative materials protect and preserve the home.

Bars of lead about to be made into paint. Great quantities of lead are so used each year

Rittase

The economic factor is also important. Houses that are not painted depreciate rapidly in value, while those which are decorated periodically are much more desirable and more salable.

Appearance. Most people are interested in beautifying their homes. The use of paints, enamels, varnishes, lacquers, and wallpapers has much to contribute to the appearance of the home. In fact, the home would be a rather shabby place without these materials.

Beautiful, harmonizing colors add much to the livability of a home. Proper color combinations have much to offer in making a home bright, tasteful, and attractive.

Sanitation. Wood and metal surfaces contain pores which have a tendency to catch dirt, grease, and germs. If these surfaces are painted, the pores are closed, and a much more sanitary condition exists. In addition, painted surfaces may be cleaned frequently without hastening the decay or rusting of the wood or metal.

EXERCISES

1. Why have paints improved in quality in the past fifty years?
2. List and describe the decorative materials used in home decoration.
3. How does paint protect a surface?
4. Explain the statement "Save the surface, and you save all."
5. Give two reasons for painting houses.

Problem 2. What are paints, enamels, varnishes, lacquers, and other decorative materials composed of, and how are they made?

Paint. Most paints consist of a pigment, an oil, a thinner, and a drier. Pigment gives body to a paint; that is, it provides covering power. A pigment also gives color to paint. The most important pigments used are white lead, zinc white, titanium oxide, and lithopone.

The composition of *white lead* is not always the same. The formula which comes nearest to representing its composition is $Pb(OH)_2 \cdot 2\ PbCO_3$. It is sometimes called basic lead carbonate. The Dutch process is most commonly used in manufacturing white lead. In this process lead is placed above acetic acid or vinegar so that the fumes of the acid attack the lead, changing it to lead acetate ($Pb(C_2H_3O_2)_2$). Heat is produced by placing fermenting tanbark on top of the earthenware pots containing the acetic acid and lead. The decomposition of the tanbark supplies carbon dioxide, which reacts with the lead acetate to form basic lead carbonate. The chemical equations to illustrate these reactions are as follows:

$$Pb + 2\ HC_2H_3O_2 \longrightarrow Pb(C_2H_3O_2)_2 + H_2\uparrow$$

$$Pb(C_2H_3O_2)_2 + 2\ HOH \longrightarrow Pb(OH)_2 + 2\ HC_2H_3O_2\uparrow$$

$$Pb(C_2H_3O_2)_2 + CO_2 + HOH \longrightarrow PbCO_3\downarrow + 2\ HC_2H_3O_2\uparrow$$

The Dutch process requires about one hundred and twenty days. A newer method, called the Carter process, requires only fifteen days, but the quality of the white lead that it produces does not equal that produced by the Dutch process.

White lead makes a paint that is easy to brush and one that has excellent covering power. Its one disadvantage is that its color darkens when exposed to air that contains gaseous sulfur compounds. White lead is reasonably priced and is used in making almost all good-quality paints.

Zinc white (ZnO) is made by heating zinc in the presence of air. The zinc reacts with the oxygen to form zinc oxide:

$$2\ Zn + O_2 \longrightarrow 2\ ZnO$$

This pigment is whiter than white lead, but it does not have as great a covering power. Gaseous sulfur compounds in the air do not change its color. Paint made from zinc white makes a harder surface than that made from white lead, but it tends to flake and crack as it ages. Correct mixtures of white lead and zinc white seem to be the best base, or pigment, for paint.

Titanium oxide (TiO_2) has several times the covering power of white lead. It is rather expensive and is generally used with white lead in the manufacture of paint.

Lithopone is made by heating zinc sulfate and barium sulfide, which results in the formation of a mixture of zinc sulfide and barium sulfate:

$$ZnSO_4 + BaS \longrightarrow ZnS + BaSO_4$$

Lithopone produces an excellent white color and has good covering power. Because it discolors in sunlight, it is used in making interior paints.

E. I. Du Pont de Nemours & Co.

This chemist is testing the covering power of titanium oxide pigment. Samples are sent to this laboratory for tests to ensure absolute uniformity

Adulterants. The cost of producing paint may be greatly reduced by using cheap pigment materials. As a rule, such pigments greatly reduce the covering power and result in a paint which is hard to apply and which is not durable after being applied. The most common adulterants used are barium sulfate ($BaSO_4$), silica (SiO_2), gypsum ($CaSO_4$), and calcium carbonate ($CaCO_3$).

Oil. In addition to acting as a suspending medium for the pigment, an oil should form a hard protective coat when it dries. The oil which most successfully meets these requirements is linseed oil. It is the most common vehicle used in paint and is obtained from flaxseed. The oil obtained by compressing this seed is called raw linseed oil. If this oil is heated with lead or manganese compounds, boiled linseed oil is made. This oil dries faster than the raw oil. When linseed oil is exposed to the air, it reacts with the oxygen, forming a tough, horny substance.

Many other oils are used, none of which is equal in quality to linseed oil. Tung oil, or China wood

Underwood & Underwood

The left and center pictures show stages in the process of manufacturing paint. The picture at the right illustrates the care with which paints are tested in the laboratory for covering power and durability

oil, obtained from a Chinese tree, is used in making enamel and has the special property of resisting destruction from moisture. Such oil vehicles as those obtained from fish, soybeans, cotton, corn, and hemp are usually considered adulterants in that they impair the quality of paint.

Thinner. A mixture of lead and oil is too thick to be applied with a brush. The addition of a thinner dilutes this mixture so that the paint becomes smooth and easy to work, and penetrates more readily. The thinner also causes more rapid drying and hardening of the paint.

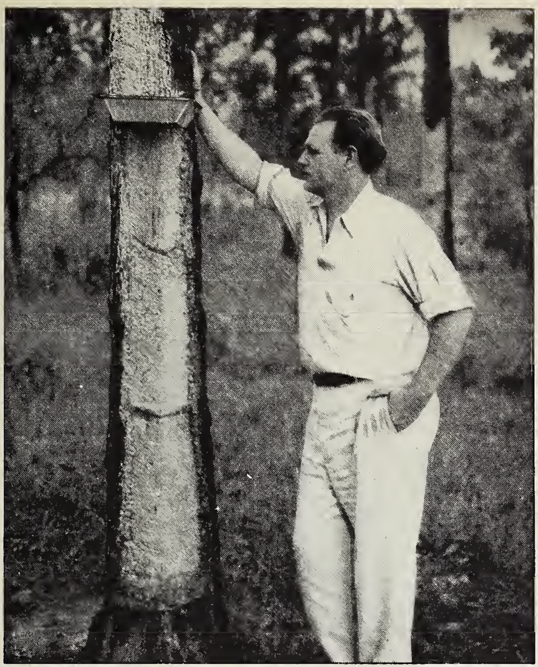
The best and most widely used thinner is turpentine. This product is obtained by distilling the sap of the pine tree. Its formula is $C_{10}H_{16}$. Frequently, inexpensive adulterant thinners are used in place of turpentine. Such adulterants as naphtha and benzine impair the quality of paint.

Drier. Without the addition of a drier, the average paint would take from two to three days to dry. With the addition of a drier, this time can be cut to from twelve to four hours. Most driers are mixtures of compounds of lead and manganese. Red lead (Pb_3O_4) and manganese dioxide (MnO_2) are commonly used. The exact chemical action by which these compounds cause paint to dry more rapidly is not known. It is supposed that they act as catalytic agents.

Color. A paint made with the ingredients heretofore mentioned—pigment, oil, thinner, and drier—is white in color. If any other color is desired, color pigments must be added. Some of the most commonly used color pigments are shown in the table which follows.

Color	Formula or Source
Yellow	
Chrome yellow	$PbCrO_4$
Zinc chrome	$ZnCrO_4$
Cadmium yellow	CdS
Red	
Vermilion	HgS
Red lead	Pb_3O_4
Indian red	Pb_2O_3
Venetian red	Fe_2O_3
Blue	
Prussian blue	$Fe_4(Fe(CN)_6)_3$
Ultramarine blue	A natural mineral
Cobalt blue	$Co_3(AlO_3)_2$
Black	
Lampblack	C
Graphite	C
Bone black	C
Ivory black	C
Green	
Chrome green Zinc green Brunswick green	Mixtures of blue and yellow pigments
Brown	
Burnt ocher Burnt umber Vandyke brown Burnt sienna	Natural earth colors. Mixtures of iron and manganese compounds

Kinds of paint. In general, there are two kinds of paint—outside and inside. The best outside paint



Ewing Galloway

Tapping pine trees for resinous sap, from which turpentine is distilled

contains mixtures of white lead, zinc oxide, and titanium dioxide as pigments. The liquid is principally linseed oil, with some turpentine. The oil dries to form a hard, tough surface which can withstand all weather conditions. The pigment of inside paint may be the same as that of outside. However, the liquid is mostly turpentine, with some linseed oil.

A paint using turpentine as the principal liquid is a dull, or flat, paint. By increasing the amount of linseed oil, the paint takes on a slight luster, or gloss. A higher gloss is obtained by adding varnish to the flat paint.

Formulas for making white house paint are as follows:

For Priming Coat on New Wood	Second Coat on New Wood; First Coat on Repaint	Finish Coat, New Wood or Repaint
3 parts white lead 4 parts linseed oil 2 parts turpentine	2 parts white lead 1 part linseed oil 1 part turpentine	1 part white lead 1 part linseed oil

Water paint. Calcimine, as water paint is commonly called, is made by mixing whiting, or gypsum ($CaSO_4 \cdot 2\,H_2O$), with glue or casein, color, and water. This paint is inexpensive and, when properly tinted, is very decorative. The use of calcimine is almost wholly restricted to the interior of the house. It may be made washable if boiled linseed oil is added to the mixture. Whitewash, a similar preparation used for outdoor work, is made by mixing slaked lime ($Ca(OH)_2$) with glue or casein and water.

Varnish. There are two types of varnishes—spirit and oil. *Spirit varnish* is made by dissolving a resin or gum in alcohol. The most commonly used varnish of this type is shellac. The resinous gum used in making shellac is obtained from a certain species of tree in India. An insect bores into the bark of the tree, feeds upon the sap, and, in so doing, produces the resinous gum. When this gum is dissolved in wood alcohol or denatured alcohol, shellac is made. When shellac is applied to wood, the alcohol evaporates, leaving the original resinous gum. A shellac surface is not as durable as that made by oil varnish.

Oil varnish of the best grade is made by dissolving gum or resin in linseed oil. To make the varnish flow more freely, turpentine is usually added. The oxidation and drying of the gum and oil produces a hard, durable surface. Cheap varnish can be made from resins of a poor quality. Copal fossil gum is one of the very best to use in making a varnish.

Enamels. An enamel is a varnish to which a pigment has been added. The pigment is usually the same as is used in house paint—white lead, zinc oxide, or titanium oxide. Because enamel can be used for inside work only, lithopone is sometimes used as the pigment. Such an enamel is inexpensive, but the quality is not the best. Enamel differs from paint in that, when it dries, it shows no brush marks.

Lacquers. A lacquer is a solution of cellulose nitrate compounds. When cotton is treated with nitric and sulfuric acids under carefully controlled conditions, cellulose nitrate compounds are formed. If the cotton is nitrated too much, a high explosive will be formed. The low-nitrated cellulose is mixed with (1) a resin, such as is used in varnish; (2) a plasticizer, usually an oil, to prevent cracking; (3) an organic solvent, such as amyl acetate, or banana oil; and (4) a color. Such a mixture produces the modern type of lacquer.

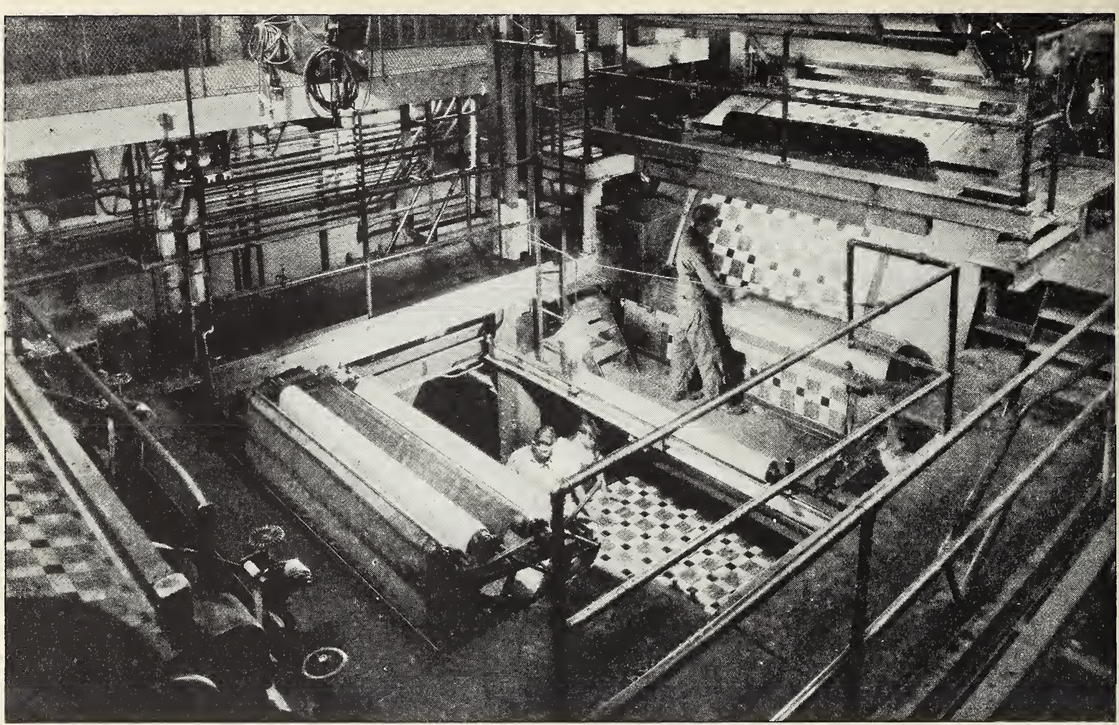
Because lacquers dry very rapidly, they must be applied carefully. The applied lacquer cannot be brushed repeatedly but must be "flowed" on. The best lacquering is done with a spray gun. Lacquer produces a hard surface which will withstand weathering. Articles painted with it can be used within a few hours after painting.

Stains. There are two kinds of stains—oil stains and dye stains. An oil stain is a paint diluted with a thinner, such as turpentine; and if the coloring is added in proper amounts, it may be used to imitate any kind of wood. Oak, walnut, and mahogany oil stains are usually permanent and effective. Dye stains are usually solutions of coal-tar dye. They are not as practical for home use as the oil stains.

Linoleum and oilcloth. These two products are closely related to paint in that they are made from linseed oil and from pigments and driers of the same type as those used in paint. Linseed oil, pigment, and cork dust are sprayed onto canvas, felt, or burlap and allowed to dry in layers until a thickness of about one inch is attained. The raw linoleum is then passed through heated rollers, and we get the finished product, inlaid linoleum. When colored designs are desired, blocks of the raw linoleum of different colors are fitted together before the heat treatment is applied. Cheap linoleums are usually thin and have the designs printed on the surface.

Oilcloth is made by painting pigmented linseed oil on thin fabric. It is then heated and decorated by printing.

Wallpaper. Many people prefer wallpaper rather than paint for interior-wall decoration. Improvements in wallpaper made during the past decade



Armstrong Cork Co.

A view of the giant rotary press which makes linoleum without the aid of a single hand. The men in the picture are inspecting the material. The machine takes the linoleum mix, forms it into a blanket, cuts out the pieces, fits them together on the burlap back, and presses them firmly and evenly to this backing so that they are virtually one piece

Here men are stripping bark from the cork oak tree. Cork is used in making linoleum, gaskets, stoppers, and many other articles of everyday use

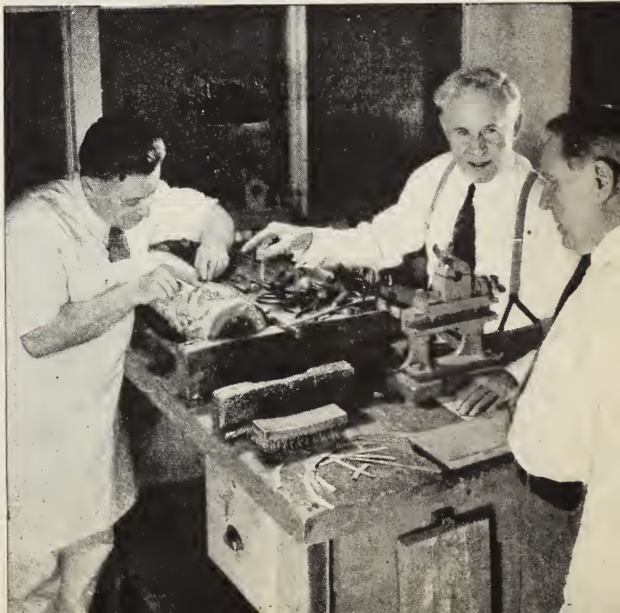
have eliminated disadvantages which formerly caused much criticism. These criticisms had to do with the fading of the colors and the fact that it was almost impossible to remove finger marks and stains from wallpaper.

It is now possible to obtain wallpaper which is practically colorfast, or lightfast. It is also possible to obtain washable wallpaper, from which almost any stain or spot can be removed with soap and water.

Wallpaper is made by painting one side of the paper with a first, or ground, coat, which is composed of pure clay mixed with a pigment and a binder. In the better grades of paper the binder is casein; in the cheaper grades it is glue. A color is added to give the paper an overall, or base color. The paper is then ready for the printing of the colored design. The design is carved on wooden rolls,—one for each color used,—and the paper is printed with the design. To make wallpaper washable, it is sprayed with a mixture of chemicals after the printing process. The ingredients of these sprays are not divulged by wallpaper companies. It is known that formaldehyde is one of the principal chemicals used.

EXERCISES

1. What is the composition of paint?
2. Write and describe the equations for making white lead.
3. What is the advantage of zinc white over white lead as a paint pigment?
4. Write the equation for making lithopone.
5. What adulterants are sometimes added to paint? What effect do they have on the paint?
6. What substances may be used as vehicles in the making of paint? Which ones are considered the best?
7. How does a drier make paint become dry more rapidly?
8. What is turpentine?
9. List and describe six different color pigments.
10. How do outside paints differ from inside paints?
11. How do water paints differ from oil paints?
12. Describe the differences between varnish, enamel, and lacquer.
13. How are oil and dye stains made?
14. Describe the processes involved in making linoleum. How does inlaid linoleum differ from printed linoleum?
15. How is wallpaper manufactured? How is it made washable.



Expert craftsmen cut designs for printing wallpaper. One roller must be used for each color in the design

Imperial Paper and Color Corporation

Imperial Paper and Color Corporation

Colors of every rainbow hue are mixed here for printing wallpaper

Problem 3. How may home-decorating be done successfully?

Decorating is a skilled trade. There are many factors involved in successful decorating which necessitate not only a great deal of study but a great amount of skill. To acquire this skill, a person must have had considerable experience in working on the job. To be able to recommend and suggest decorations which will be suitable and which will give personality to a house requires much knowledge and artistic ability. The hanging of wallpaper and the application of paints, varnishes, enamels, and lacquers require much skill. For these reasons, you can be more certain that the work will be satisfactory if it is done by a competent, skilled decorator than if you try to do it yourself.

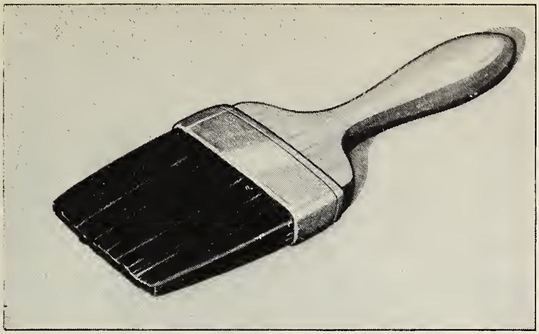
Many homeowners enjoy planning and doing the job of decorating the home. For some, this activity is a hobby, a way of using the hands and a means of artistic expression. For others, it is a way of making the home attractive without great expense. Certainly both these are worthy reasons, and it is for these homeowners that information is given here about methods to use in the successful decoration of the home.

How should the surface be prepared for painting? Many a job of painting has been ruined because the surface was not properly prepared for the new paint to be applied. It is essential that the surface to be painted be free from dirt and grease; otherwise the paint will not grip the surface and become firmly bound to it. Dirt and grease may be removed in several ways. Trisodium phosphate (Na_3PO_4) is generally effective if mixed in the proportion of one to two teaspoonfuls to a gallon of water. Where the old paint has become very greasy and dirty, as in a kitchen, it may be necessary to use a laundry soap or a mild abrasive, such as cleansing powder. Either of these materials will remove some of the paint; but if it is rinsed off the surface, it will leave the surface free from grease and dirt.

The next step is to see that the surface is as smooth as possible. Nails that are protruding should be driven into wood or removed from a plastered surface. All holes in wood should be filled with putty. Cracks in plaster should be repaired. If the surface has been painted before, all loose or cracked paint should be removed. If the old paint is glossy, it should be sandpapered. When painting indoors, all hardware, such as doorknobs and electric switches, should be removed. Knots in wood or places where resin is coming out of the wood should be coated with shellac before painting.

If a painted surface is in bad condition, it may be necessary to remove the paint. This may be done by mixing one part of lye ($NaOH$), three parts of hydrated lime ($Ca(OH)_2$), and enough water so that the mixture can be brushed on the surface. If this paste is allowed to remain for from fifteen to thirty minutes, the paint can be scraped off. Great care should be taken if this mixture is used because lye is very caustic and will burn the skin. In addition, unless the excess is neutralized with vinegar, the wood surface will be eaten away. Wood alcohol (CH_3OH) may also be used to remove paint. The alcohol is brushed on and allowed to act for about fifteen minutes; then the paint can be scraped off. Alcohol also is dangerous because of the poisonous fumes given off.

Applying the paint. After the cleaning has been done and the surface is perfectly dry, the paint may be applied. In addition to using a good quality of paint, varnish, lacquer, or enamel, it is important to use a good brush. The size of the brush varies with the desires of the individual, but, as a rule, for open work, a large three-inch brush will save much time, whereas for sash work, a small



A good paintbrush is essential to good painting

one-inch brush is usually better. The best brushes are made of hog bristles set in vulcanized rubber. Such brushes have live, springy bristles. Cheap brushes of horsehair are usually soft and flabby and cause much paint to be wasted. For inside or outside painting, a brush with bristles from three to four inches in length is advisable. When finishing with enamel, lacquer, and varnish, the bristles should be less than three inches in length.

The brush should be dipped into the paint to a depth equal to about one half the length of the bristles. Excess paint should be removed by brushing the bristles lightly against the inner edge of the can. The painter should select a square or rectangular area which can be covered well with the amount of paint in the brush. The paint-filled brush should be started in the center of this area and brushed in all directions. The painted strip should not be so wide that the paint will harden before the adjacent strip can be painted. For new wood the first, or priming, coat should be thinned with linseed oil and turpentine and brushed hard, so that the paint will penetrate the pores of the wood. A succeeding coat should never be applied until the preceding coat has dried for at least two days, preferably for a week.

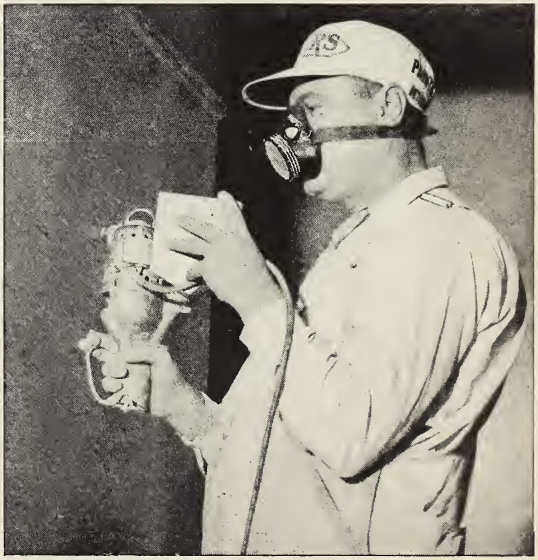
Varnish, enamel, or lacquer should not be brushed in all directions. It should be "flowed" on, that is, brushed from one spot on the surface with straight even strokes until it is evenly spread over the area.

Suggestions and notes for the house-painter.

1. One gallon of paint should cover at least 750 square feet of painted surface or about 500 square feet of unpainted surface.
2. Paint should not be applied when the temperature is below 50° F.
3. Paint should never be applied unless the surface is thoroughly dry.
4. Paint with the tips of the bristles.
5. Three thin coats of paint will wear and last longer than two thick coats.
6. Blistering is generally due to moisture coming from the material which was painted.
7. For thinning follow the directions given on ready-mix cans or follow a reliable formula if you are mixing your own paint.
8. Cover tightly all paint cans when not in use.
9. Stir frequently the paint that you are using.
10. Do not paint with the sun shining directly on the surface.
11. Use boiled linseed oil only when quicker drying is desired.
12. Never apply lacquer over enamel, paint, or varnish.
13. Never use inside paint, enamel, or varnish for outside surfaces.
14. Ready-mixed paint should be stirred thoroughly before using.

A person should wear a mask when painting with a spray gun. Why?

Ewing Galloway



Care of brushes. The life of a paintbrush may be lessened by more than one half if improper care is used. A brush should never be stood on its bristles. Such treatment will soon cause the bristles to become bent and unshapely. When a brush is not to be used for some time, it should be wrapped in wax or oil paper and laid on its side.

Brushes used for varnishing or enameling should be cleaned with turpentine. A shellac brush should be cleaned with alcohol. Brushes containing ordinary house paint can be cleaned with turpentine, gasoline, or benzine. After thorough cleansing, the brush should be stored in moistureproof paper or paper bags.

If paint dries in a brush, it can be removed with commercial paint-cleaners. These cleaners usually contain trisodium phosphate. A brush so cleaned will never be restored to its original form and quality.

Dangers. Persons who work constantly with paint should take every precaution against lead poisoning. Lead compounds enter the body through the mouth and nose and accumulate in the tissues of the body. Painting with a spray gun makes much more likely the accumulation of enough lead in the body to cause poisoning than painting with a brush. Lead poisoning may cause stomach disorders, nerve irritation, and kidney ailments which sometimes result in death. Masks are now being used by many painters to filter the air while they are painting.

Painting should never be done in a room that is not well ventilated. Many paints give off gases which, if enclosed in a room, may become ignited and explode.

Color selections. At one time it was possible to give definite information about color combinations. It could be said that certain colors, such as green and blue, "clashed" when used together. It was also possible to say that other colors harmonized. In recent years scientists have produced so many new shades and hues of every color that it is impossible for anyone to make hard-and-fast rules governing color harmony.

At the present time it is the custom to select colors for home decoration on the basis of their effect on the members of the family, as well as on the basis of the power that colors have to give "character" and "personality" to a home. Restful colors to one person may be the opposite to another; the usual cool colors—blue, gray, and green—may have on some people an effect other than that of coolness.

Color selection for home decoration is of great importance in making the home livable and attractive. It demands careful consideration. The selection of colors necessitates careful study of the likes and dislikes of every member of the family. It also requires knowledge of what constitutes harmony between the colors of furnishings and those of decorations, as well as what color combinations will "bring out" the most that is possible in a home.

EXERCISES

1. Is it advisable to do your own home-decorating? Why or why not?
2. How should the surface be prepared for painting?
3. What are the essential factors to remember in applying paint?
4. What causes paint to blister?
5. Approximately how much paint would be required to cover with one coat an unpainted house 50 feet long by 30 feet wide by 15 feet high?
6. What are some common do's and don't's which should be observed if you are doing your own painting?
7. How should paintbrushes be cared for?
8. What precautions should be observed in using paint?

Problem 4. What factors should be taken into consideration in purchasing decorative materials?

Good workmanship essential. When painting is being done by a skilled, or master, painter, the cost of the labor is generally about twice that of the paint. Therefore it is uneconomical to use an inferior quality of paint. Also, since one is paying for a high quality of workmanship, one should be sure that one gets it.

Nothing is saved by waiting too long between paint jobs. Although the climate and other conditions may cause some variations, it is safe to say that repainting should be done every four to six years. If painting is not done that often, it is usually necessary to apply an extra coat; and there is in addition the fact that the surface becomes unsightly.

Buy quality materials. Information that you have been given about the substances used in making

Paint made by a reliable manufacturer has the ingredients plainly declared on the label

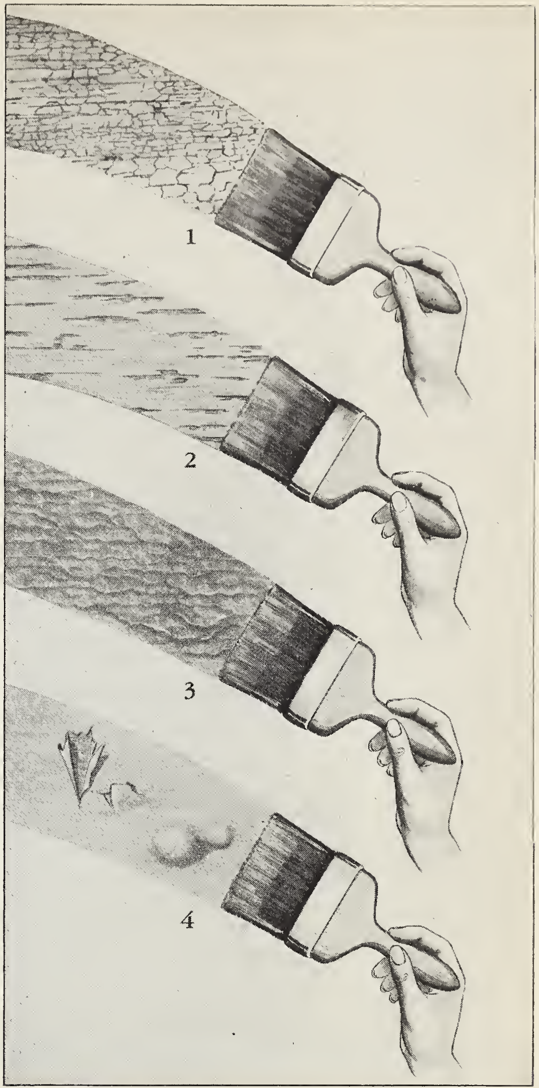
paints, varnishes, enamels, and lacquers should be sufficient for you to recognize how easy it is to adulterate these materials and thereby destroy their quality. You can buy different qualities of these decorative materials; as a rule, those materials which are priced low are inferior in quality.

In mixing your own paints, varnishes, and enamels, be sure that the ingredients are of the best quality. White lead, zinc oxide, and titanium oxide can be bought in original containers with the purity stated on the label. Linseed oil and turpentine should be bought in sealed containers.

If you buy ready-mixed decorative materials, investigate thoroughly those which are offered to you at especially low prices. Remember that a manufacturer who makes a good quality of paint is never ashamed to list on the label of the can the constituents used. Buy on the basis of the statements that reliable manufacturers make on the labels.

Do not be misled by the statement that a paint is a good "lead and oil" paint. It is necessary to know how much white lead and what kind of oil is in the paint in order that the quality can be determined. Talk to reliable retailers of decorative materials. You can learn a great deal from them which will help you to be an intelligent buyer.

It is not advisable or economical to mix your own decorative materials if only a small amount is needed. If a gallon or two of the material is sufficient for the job, it is better to buy ready-mixed paint,



House Beautiful

In repainting or in new painting, precautions must be exercised in order to avoid certain defects. (1) Checking and alligatoring, caused by a too-soft undercoat. In repainting remove scales with a wire brush. In new work each coat should be allowed to dry thoroughly. (2) Cracking and scaling, caused by "hard" paint. In repainting remove old paint. In new painting use a paint which retains its elasticity. (3) Wrinkling, caused by a too-thick coat of paint. In repainting sand the surface thoroughly. In new painting brush to a thin film. (4) Blistering and peeling, caused by moisture in wood. In repainting scrape off old paint. In new painting make sure that the surface is dry before painting varnish, or enamel. It is not advisable to make your own lacquers.

Refinishing a decorated surface. If a repaint job is being done, it is essential that the new paint, varnish, or enamel adhere to and bind with the old. Experience has taught experts that the new decorative materials must be made of the same kind and quality of ingredients as the old if the proper sealing is to take place. It is not uncommon for varnish which is used to cover an already varnished floor to scar and crack easily. This is generally because the new varnish is a different kind from the old.

Selecting a decorator. If you do not do your own decorating, it is essential that you use great care in selecting a decorator. There are many precautions that can and should be taken.

In the first place, thorough investigation of the work done by the decorator is important. Find out where he is working at the time that you begin to need him, and inspect the work that he is doing. Look at some of his work which is several years old and talk to the homeowners and get their judgment of the quality of his work. Many times it is possible to obtain the names of good decorators from local paint-retailers. Many of these retailers even go so far as to guarantee the work. Insist upon a bid for your work, with specifications. Reliable decorators are more than willing to do this.

Lastly select a decorator who has some artistic sense. Such a workman can often make suggestions and plan his job so that a much more pleasing appearance will result.

EXERCISES

1. How often should a house be repainted?
2. What are the differences between poor-quality paints and good-quality paints?
3. How should a previously decorated surface be refinished?
4. How can you know a good decorator?

PROBLEMS FOR FURTHER STUDY

1. How is white lead manufactured by the Carter process?
2. Where are the resins used in varnishes obtained? What is their chemical nature?
3. Make a survey of your home and determine the kinds of materials needed and their cost of application.
4. Visit an interior decorator and get the latest information regarding color harmony in the home.
5. What is tung oil, and how is it obtained? From what country is it obtained?
6. Where do the best brush bristles come from, and how are they obtained?
7. Why is the structural steel of bridges and large buildings painted with red or yellow paint? What is its composition? Why is red paint cheap?
8. What is aluminum paint? How is it used? What are its advantages? How is it made?
9. What are the best methods of surfacing the different types of flooring?
10. What is sandpaper, and how is it made?

UNIT EXERCISES

The statements which follow are incomplete. On a separate sheet of paper write whatever is necessary to complete each statement correctly. Do not write in this book.

1. The --(?)-- of colors used in paints was very limited before chemists became active in the field of colors.
2. Decorative materials are used in the home for the following reasons: --(?)--, --(?)--, and --(?)--.
3. Painting preserves a surface because it prevents --(?)--.
4. Most paints consist of --(?)--, thinners, driers, and --(?)--.
5. White lead has the formula --(?)-- and is known as a --(?)-- salt.
6. Most white lead is made by the --(?)-- process.
7. Gaseous --(?)-- compounds cause white-lead paint to darken.
8. Titanium oxide pigment has great --(?)-- power.
9. Barium --(?)-- is considered an adulterant in paints.
10. Linseed oil oxidizes slowly when exposed to --(?)--.
11. A common thinner for paints is --(?)--.
12. Red pigments usually contain --(?)-- or --(?)-- oxides.
13. Inside paints contain more --(?)-- than outside paints.
14. Gloss in a paint may be obtained by using --(?)--.
15. Water paints consist of --(?)-- (formula) and --(?)-- mixed with water.
16. Spirit varnish is made by dissolving --(?)-- in --(?)--.
17. An enamel is a --(?)-- to which has been added a --(?)--.
18. Lacquers contain cellulose --(?)-- and an organic solvent, such as --(?)--.
19. Lacquers are best applied with a --(?)--.

20. Linoleum is made from --(?)-- oil, pigment, and --(?)--.

21. Washable wallpaper is wallpaper which has been sprayed with a compound containing --(?)--.

22. All dirt and --(?)-- must be removed from the surface before paint is applied.

23. Wallpaper is made by applying to paper a ground coat composed of --(?)--, a pigment, and a binder, such as --(?)--.

24. A wall-cleaner may be made by mixing --(?)-- with water.

25. Paint may be removed by rubbing with --(?)-- or by applying a paste made from --(?)-- and --(?)--.

26. The best paintbrushes are made from --(?)-- bristles.

27. Paintbrushes may be cleaned with --(?)--.

28. Houses should be repainted every --(?)-- or --(?)-- years.

29. Both ready-mixed paint and the ingredients for paint should be purchased on the basis of the statements on the --(?)--.

30. In revarnishing a previously varnished surface, the --(?)-- kind of varnish should be used.

REFERENCES FOR FURTHER READING

Beery, Pauline G. *Chemistry Applied to the Home and Community.* J. B. Lippincott Company, Philadelphia, 1926.

Dalzell, Ralph, and Sabin, Alvah H. *Painting and Decorating.* American Technical Society, Chicago, 1939.

McLain, Jean. *The Romance of Modern Decoration.* Imperial Color and Paper Corporation, Glenn Falls, New York.

Reich, Edward, and Siegler, Carlton J. *Consumer Goods: How to Know and Use Them.* American Book Company, New York, 1937.

Van Vlack, C. H. *Selecting and Applying Paints.* Iowa State College of Agriculture and Mechanical Arts Extension Bulletin No. 261, Ames, Iowa, July, 1939.

Whitman, Roger B. *First Aid for the Ailing House.* McGraw-Hill Book Company, Inc., New York, 1934.

Know and Use Them. American Book Company, New York, 1937.

Painting on the Farm, Farmers Bulletin No. 1452, United States Department of Agriculture, Washington, D.C. 5 cents.

Wood Handbook, United States Department of Agriculture, Washington, D.C. 25 cents.

UNIT 28

The Chemistry of Gardening

A home is never quite complete unless it is properly landscaped. A velvety lawn, well-placed trees and shrubs, and artistically planned flower gardens are almost as necessary as the house. Almost everyone, at some time or other, has engaged in gardening.

It is fun to plan a garden. It is exciting and satisfying to watch plants grow from seeds or seedlings to the stage of maturity where they serve a useful purpose. Few things can be more thrilling or more satisfying than to watch carefully and nurture patiently a flower seed from the day it is placed in the soil to the day it produces a beautiful flower.

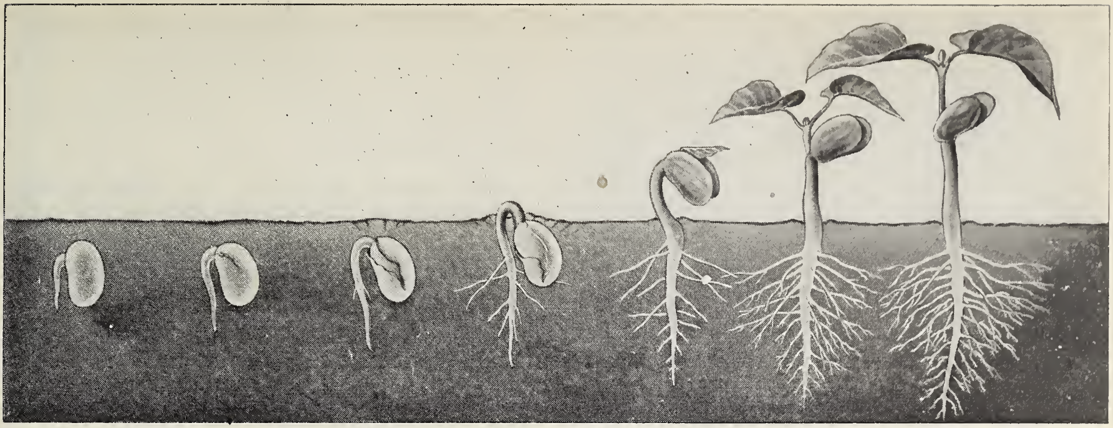
Gardening provides many opportunities for making life fuller and more pleasurable. It is a healthful avocation because those who tend a garden are assured of plenty of sunshine, outdoor exercise, and fresh air. Gardening offers many opportunities for the expression of artistic ability. It provides a pleasant diversion from the usual routine of the day. Those who have a garden project gain a feeling of satisfaction from being able to produce something which is useful. Many enjoy especially the growing of vegetables because in this way food is produced for family use.

PURPOSES TO BE ACHIEVED

1. To help you to become a more successful gardener.
2. To aid you in caring for a garden scientifically.
3. To give you an understanding of the factors which control the growth of plants.
4. To help you to realize the unlimited possibilities of gardening as an avocation.
5. To familiarize you with the latest chemical discoveries which are helpful in gardening.

New developments in the chemistry of plants, fertilizers, and insect control have made possible more beautiful and more productive home gardens

Ewing Galloway



Stages in the germination of a seed [1]

PROBLEMS TO BE SOLVED

1. What chemistry is involved in gardening?
2. How do plants grow?
3. Why is it necessary to use fertilizers?
4. How can insects, diseases, and weeds that threaten the growth of plants be controlled?
5. How are plants grown without soil?

Problem 1. What chemistry is involved in gardening?

Plant growth involves chemistry. Successful gardening would not be possible without the aid of chemistry. The growth of plants is itself a chemical process. The chemicals in the soil and in the air are essential to this growth.

The importance of fertilizers is generally recognized by those who engage in gardening. The chemical elements which fertilizers, both natural and synthetic, supply to the soil are necessary for the proper growth of plants.

Plants are subject to destruction by insects and diseases. Modern science has provided chemical substances which make it possible for the gardener to control insects and diseases.

A recent addition to the art of gardening is that of growing plants without soil. Chemical solutions can supply the same nutrients that are supplied by the soil. Hence a new type of home gardening is increasing in popularity by leaps and bounds.

EXERCISES

1. What does a carefully planned garden add to a home?
2. In what ways is chemistry related to gardening?
3. Define the word *fertilizer.*

Problem 2. How do plants grow?

Growth begins with seed. Almost all the plants grown in the home garden are obtained from seeds. Incased in the seed is the embryo, containing cells which are alive, though dormant, and a food supply which is used in the early stages of germination.

Germination of seeds. Most seeds need moisture, warmth, and air for germination. When these three requirements are present, the embryo awakens and is fed by the food stored in the seed. First, the roots grow downward in search of new sources of food. Then a stem is forced upward; and when leaves are formed, the plant begins manufacturing its own food.

Plants are food factories. The raw materials used in the manufacture of food within the plant are obtained from two sources—the soil and the air. The soil supplies water, in which mineral compounds are dissolved, and the air furnishes carbon dioxide.

The water and the mineral substances move from the soil into the roots by osmosis. The woody part, the center, of the stem carries these materials to the leaves. The food-manufacturing process is carried on in the leaves. The green coloring matter, chlorophyll ($C_{55}H_{72}O_5N_4Mg$), of the leaves possesses the property of absorbing the sunlight, especially the light rays at the red end of the spectrum, and also acts as a catalyst. The leaves take in carbon dioxide from the air through tiny surface openings called stomata. The heat that is absorbed and the catalytic action of the chlorophyll cause the water and carbon dioxide to unite to form glucose and oxygen. Such a reaction is known as photosynthesis.

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[1] Adapted from Curtis and Sherman's *Workbook to Accompany Biology for Today*, Ginn and Company.

$$6\,CO_2 + 6\,H_2O \longrightarrow C_6H_{12}O_6 + 6\,O_2$$

Photosynthesis takes place only in the presence of sunlight, and it decreases rapidly as the temperature drops below the average for summer.

Through a chemical reaction of which little is known, fats, proteins, starches, resins, perfumes, and other products are manufactured by the plant from the simple sugar glucose.

These reactions have never been duplicated by man. When glucose, fats, and proteins can be prepared in the laboratory from carbon dioxide and water, man will become independent of plants as a source of food.

Plants use manufactured food. The food produced by a plant is used to supply energy for the growth of the plant. This food is transmitted from the leaf to all parts of the plant where growth is taking place. This may result in the formation of edible fruits and vegetables or the production of beautiful flowers.

A small amount of the food produced by plants is used in respiration similar to that which takes place in animals. Plants breathe in oxygen, which unites with the glucose to form carbon dioxide, water, and energy:

$$C_6H_{12}O_6 + 6\,O_2 \longrightarrow 6\,CO_2 + H_2O + \text{released energy}$$

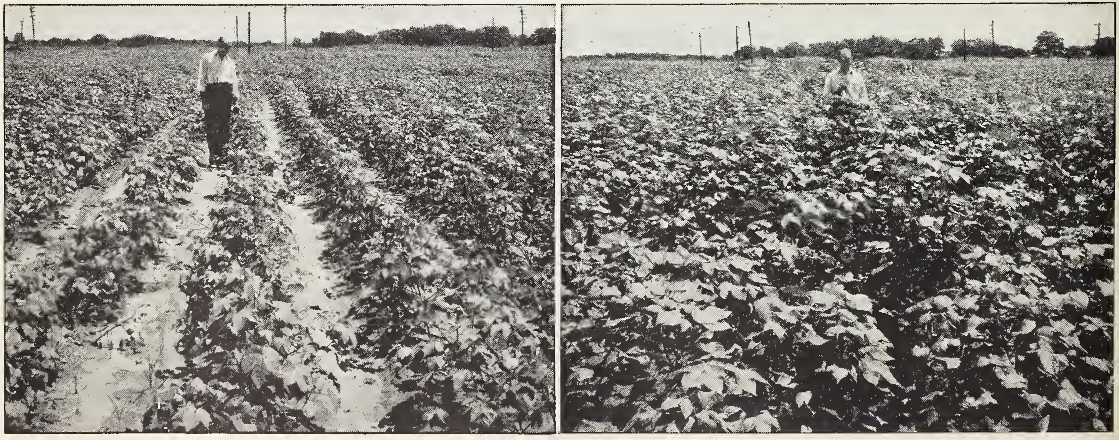
Soil—an important source of plant food. There are ten important elements which are essential to the growth of a plant. They are carbon, oxygen, hydrogen, nitrogen, potassium, phosphorus, sulfur, calcium, magnesium, and iron. There are also other elements, such as boron, manganese, copper, and zinc, which are essential in small quantities for the growth of some plants. All these elements, except carbon and oxygen, are obtained by the plant from the soil.

Soil is a mixture of disintegrated rocks and humus (decayed vegetable or animal matter). When plants decay or when animal matter decays, humus, which is rich in plant food, is produced. Some of the elements necessary for plant life are supplied by the disintegrated rocks. For example, limestone will supply calcium, granite will furnish potassium, and phosphate rocks will yield phosphorus. However, most of the available elements for plant growth are obtained from humus.

The elements essential for plant growth must be present in the soil in soluble compounds if they are to be available for plant use. They must be dissolved by the water before they can be taken in through the roots.

A field of cotton which has received no fertilizer compared with the same field the next season after fertilizer has been added

Texas Agriculture Experiment Station



EXERCISES

1. What conditions must be met before seeds will germinate?
2. Explain the statement that green plants are food-manufacturing factories.
3. Write the equation for the making of glucose as it takes place within a plant.
4. Define the word *photosynthesis*.
5. Why do plants make food?
6. What chemical elements are essential to plant growth?
7. What is the meaning of the word *soil*?
8. What is the difference between ground-up rocks and soil?

Soil of poor and soil of good tilth [1]

Problem 3. Why is it necessary to use fertilizers?

Growing plants exhaust the fertility of the soil. Years ago the soil in unsettled parts of the country where vegetation flourished was rich in the elements necessary for plant growth. This condition existed because nothing was removed from the soil, so that the decaying vegetation returned to the soil as much plant food as was taken from it.

When farmers began growing crops on this land, they failed to recognize the fact that they were taking the elements necessary for plant growth out of the soil and giving back nothing in return. Under such conditions, soil becomes worn out, and the supply of plant food is exhausted.

It is not uncommon for those who have a home garden to fail to maintain the fertility of the soil. You cannot have a good vegetable or flower garden, a green, velvety lawn, and beautiful shrubs and trees if the elements in the soil necessary to growth are depleted. It is just as essential to plants that they obtain food as it is to your body that it have regular nourishment.

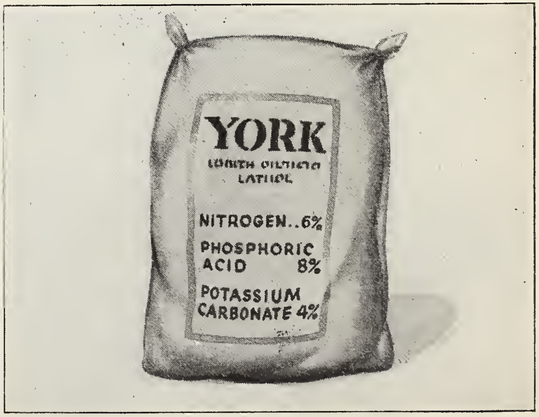
Because plants do rob the soil of the growth elements, it is imperative that fertilizers be used. Three of the elements, nitrogen, phosphorus, and potassium, are used in large quantities by plants and frequently have to be added to the soil. There is but little danger of depleting the other elements, although occasionally calcium, manganese, and magnesium are used up.

Kinds of fertilizers. If you expect the plants, shrubs, and trees of the garden to thrive, it is imperative that the soil be fertilized regularly. If you are going to use fertilizers, you should become familiar with the many kinds which are available.

Manures, consisting of the excrement of farm animals, have two purposes: (1) They add humus to the soil. This gives the soil tilth, or looseness. (2) They furnish the soil with a good supply of nitrogen, phosphorus, and potassium. Much of the nutritional value of manure is lost if it is allowed to dry out over a long period of time.

There are several disadvantages to the use of manure. The weed seeds present in this type of fertilizer may cause an excessive growth of weeds in garden and lawn. Also, manure is generally more expen-

Commercial fertilizers usually come in 100-pound bags with the chemical contents printed on the outside



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[1] Reproduced from Grimes and Holton's *Modern Agriculture*, Revised Edition, Ginn and Company.

sive than commercial fertilizers. When placed on a lawn, manure is usually odorous and unsightly. However, the looseness of texture which it gives to the soil is of the utmost importance and cannot be obtained from commercial fertilizers.

When manure is used, it should be spread on the lawn, the garden, and around shrubs in the fall of the year. In early spring, where spading is necessary, the manure should be turned under. Where commercial fertilizers are used, it is necessary to add manure, leaf mold, peat moss, or some other humus material to the soil every few years; otherwise the soil will become hard and compact.

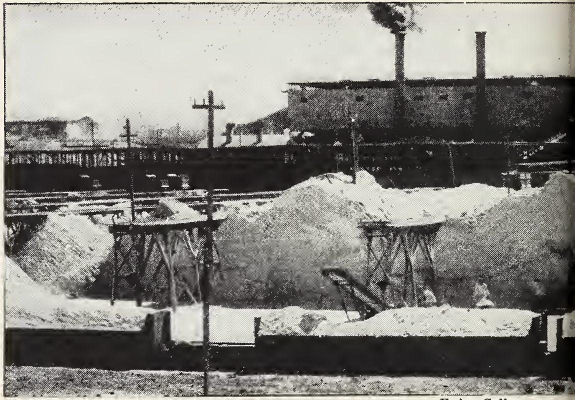
Commercial fertilizers are gaining in popularity with gardeners. This increase in use is due partly to the fact that the supply of natural fertilizer is limited and also to the fact that commercial fertilizers are convenient to handle and to apply.

Commercial fertilizers are sold according to formula. Thus the formula of a certain brand of fertilizer is given as 6–8–4, which guarantees a minimum of 6 per cent nitrogen, 8 per cent phosphoric acid, and 4 per cent potassium carbonate, or potash. Such fertilizers should be bought after an analysis has been made of the soil on which they are to be used and after a consideration of the requirements of the plants to be grown.

The compounds used in a commercial fertilizer are obtained from many different sources. The proportions in which these compounds are mixed are determined by the use to be made of the mixture. There are several companies which put out standard mixtures that are generally adaptable to garden use.

Sources of nitrogen compounds. The nitrogen compounds used in commercial fertilizers are obtained (1) from the nitrate beds of Chile (in South

These nitrate beds seem to have an almost inexhaustible supply



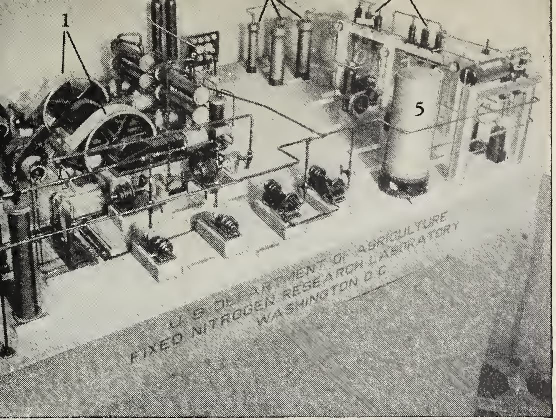
Ewing Galloway

One of the principal nitrate refineries

The Nitrate Industry in Chile

Nitrate tanks with the nitrate solution drained off

Nitrate is shipped to the United States in bulk and bagged here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U. S. DEPARTMENT OF AGRICULTURE
FIXED NITROGEN RESEARCH LABORATORY
WASHINGTON D.C.

United States Department of Agriculture

A model plant for the making of ammonia by the direct combination of nitrogen and hydrogen (Haber process). In (1) the gases are compressed, and in (2), (3), and (4) the compressed gases are purified and caused to unite in the presence of platinum, a catalytic agent. The ammonia which is produced is stored in (5)

America) in the form of sodium nitrate ($NaNO_3$); (2) from organic matter, such as cottonseed meal, the waste of slaughterhouses, the sludge from sewage-disposal plants, and fish scraps; (3) from the nitrogen of the atmosphere. The nitrogen of the atmosphere is made into compounds by chemical fixation. Two methods are used: (1) the Haber process and (2) the cyanamide process.

The Haber process. The German chemist Haber discovered that a mixture of nitrogen and hydrogen gases would unite to form ammonia if subjected to high temperature and pressure in the presence of a suitable catalyst, iron. The reaction may be expressed as follows:

$$N_2 + 3\,H_2 \rightleftarrows 2\,NH_3$$

The ammonia must be dissolved in water. It can then be made to react with sulfuric acid to produce ammonium sulfate ($(NH_4)_2SO_4$), a constituent of many commercial fertilizers.

This process has been of great economic importance. It assured Germany, during the first World War, of an unlimited supply of fertilizers and explosives.

The cyanamide process. In the cyanamide process nitrogen of the air is passed over heated calcium carbide (CaC_2), and the following reaction takes place:

$$CaC_2 + N_2 \longrightarrow CaCN_2 + C$$

The calcium cyanamide is often used as one of the ingredients of commercial fertilizers.

Sources of phosphorous compounds. The sources of phosphorous compounds used in commercial fertilizers are (1) ground bones obtained from packing plants, (2) the basic slag of steel furnaces, (3) natural deposits of phosphate rock. Large natural deposits of phosphate rock are found in Florida, Tennessee, and South Carolina. This rock occurs as calcium phosphate ($Ca_3(PO_4)_2$), which is insoluble and therefore not usable as a fertilizer. It is made soluble by causing the rock phosphate to react with sulfuric acid:

$$Ca_3(PO_4)_2 + 2\,H_2SO_4 \longrightarrow 2\,CaSO_4 + Ca(H_2PO_4)_2$$

The monocalcium phosphate ($Ca(H_2PO_4)_2$) is soluble and adaptable for use as a fertilizer. The calcium sulfate is also a plant food but increases the shipping weight of the product. Some companies now use phosphoric acid in place of sulfuric acid, thereby eliminating the calcium sulfate produced.

Sources of potassium compounds. Before the first World War our chief source of potassium salts was Germany. The World War cut off this supply, and the fertilizer industries of the United States had to find new sources of potassium. There are many minor sources, such as wood ashes and kelp ashes, but they are of no commercial importance. Several valuable natural salt deposits have been uncovered in Nevada, New Mexico, and California. Potassium salts obtained from dried-up lakes and from the water of lakes rich in these salts are used as fertilizers.

Phosphate rock used in making superphosphate fertilizers is obtained from this Florida deposit

From this salt deposit potassium salts are extracted for use in the manufacture of fertilizers

United States Department of Agriculture

An alfalfa field seeded with and without lime in Essex County, New York

Because potassium salts are scarce, they are expensive when used for fertilizing purposes. However, they are very essential to the growth of plants.

Soil often needs lime. When a soil becomes "sour," or acid, many plants, such as grass, will not grow in it. For this reason, in some localities, it is necessary to lime the soil. If slaked lime ($Ca(OH)_2$) is added to the soil, it neutralizes the acid, and the soil is said to be "sweetened." Sometimes ground limestone ($CaCO_3$) is used; lime from this source, although it acts slowly, will not have a burning effect, as slaked lime often does.

Lime also aids in the liberation of plant food, so that the food becomes soluble and available to the plants. This may be beneficial at times but, if continued, will rob the soil unduly. For this reason, lime is often spoken of as "making a rich father but a poor son."

Plant hormones. During the past few years a new development in plant growth has been introduced. Chemical substances have been discovered which stimulate the growth of the roots of plants. These substances are called plant hormones.

When these hormones are applied to the soil around a growing plant, the growth of the roots is hastened. In fact, experiments show that when the hormones are applied to the leaves and stems of plants, roots will grow from the treated areas. The use of these hormones has made it possible to cause roots to grow faster on cuttings, as well as to make roots grow on cuttings which do not ordinarily grow roots.

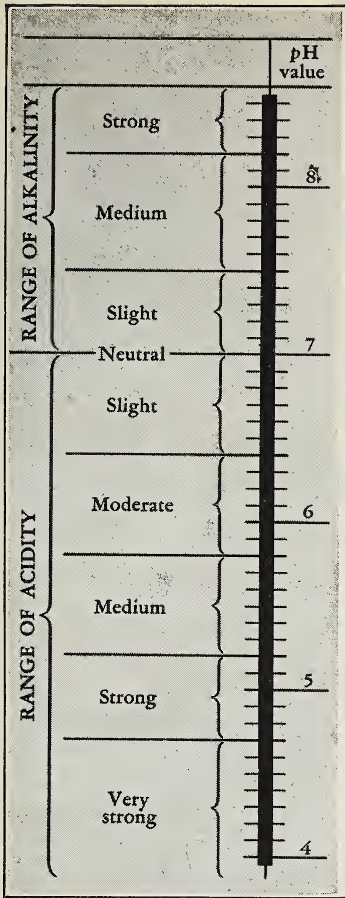
There are many of these plant hormones. Two that are being used are indole acetic acid ($C_{10}H_9O_2N$) and vitamin B_1($C_{12}H_{18}ON_4SCl_2$). Plant hormones may now be purchased in almost every community.

Cautions in applying commercial fertilizers. Most companies that make commercial fertilizers have made a thorough study of how to apply them. Unless the directions in the package are followed carefully, there is danger of "burning" garden plants. Twice as much of the fertilizer as is recommended will not produce double results. In fact, excessive amounts may ruin the entire lawn or garden. The area where these fertilizers are applied should always be thoroughly drenched with water immediately after applying.

Analyzing soils. If you are having difficulty in growing lawns, shrubs, or plants, you should have your soil analyzed. Your state experiment station, which is often a branch of the state agricultural college, will usually perform this service free. An analysis of your soil will show what elements are deficient, and you can buy a fertilizer which will make up for the deficiencies. Acid soils may be detected by testing with blue litmus paper.

EXERCISES

1. What is meant by the phrase *mining the soil*?
2. What chemical elements are most easily depleted in the soil?
3. What valuable materials does manure add to the soil?



The *p*H value, sometimes referred to as the hydrogen-ion concentration, may be used in measuring acidity or alkalinity. A *p*H value of 7.0 indicates neutrality; a *p*H value below 7.0 indicates acidity; a *p*H value above 7.0 indicates alkalinity. This means of indicating acidity or alkalinity is used widely in industry.

The *p*H value is also frequently used in agriculture to indicate the condition of the soil—whether it is "sour" (acid) or "sweet" (alkaline). Some crops require a sweet soil, whereas others require an acid soil. If the acidity of a soil is too high, lime must be applied in suitable amounts to bring the soil to an appropriate *p*H value.

With the following *p*H values are listed some crops which are suitable for the range given:

*p*H 6.5 to *p*H 7.5: alfalfa, sweet clover

*p*H 6.0 to *p*H 7.0: red clover, white clover, sugar beets, cabbage, beans, peas, carrots, cucumbers

*p*H 5.5 to *p*H 6.5: wheat, oats, barley, rye, most grasses, onions, tomatoes, most fruits

*p*H 5.0 to *p*H 5.5: potatoes, tobacco, watermelons, blueberries, certain flowers

Less than *p*H 5.0: soil too acid; should be limed

American Agricultural Chemical Company

Lime requirements of crops

4. What are the differences between manure and commercial fertilizers?

5. What are the sources of commercial fertilizers?

6. How may the nitrogen of the air be "fixed" into compounds suitable for fertilizers?

7. Describe, using equations, the Haber process and the cyanamide process for making fertilizers.

8. Write the equation for making monocalcium phosphate.

9. What is the difference in properties between monocalcium phosphate and tricalcium phosphate?

10. What is the value of adding lime to soil?

11. Why are plant hormones sometimes applied to plants?

12. What precautions should be observed in applying fertilizers?

13. Where may you have soil analyzed?

A United States Department of Agriculture chemist analyzing soil for mineral deficiencies

United States Department of Agriculture, Bureau of Entomology and Plant Quarantine

The plants in the foreground have been attacked by Colorado potato beetle; the plants in the background were sprayed with an insecticide and were not attacked

Problem 4. How can insects, diseases, and weeds that threaten the growth of plants be controlled?

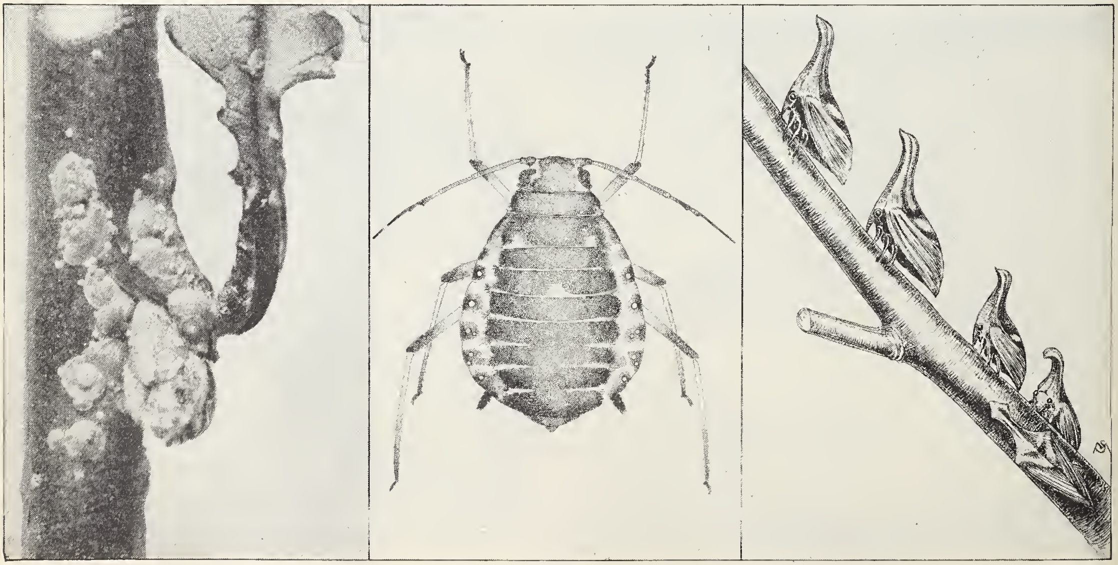
Pests destroy the beauty of the home garden. Many a garden is ruined by the ravages of insects, diseases, and weeds because the gardener is not vigilant in caring for it. These pests can mutilate a garden to the extent of making it unsightly. Dandelions, plantain, and other weeds may completely choke out the growth of grass; insects may destroy foliage and kill vegetables, flowers, and shrubs; and fungus diseases may inhibit the growth and mar the appearance of beautiful trees and shrubs.

If you want a garden that is a credit to your home, it is essential that the pests which attack it be controlled. Careful examinations of plants must be made regularly. You must learn to recognize these pests and learn how to control them.

In the first place, the plants and seeds that you select should be disease-free and disease-resistant. Healthy plants are less susceptible to pests than unhealthy ones. The next essential is to maintain clean culture. Weeds serve as a refuge for insects and diseases, and these pests soon spread to the flowers, vegetables, shrubs, or trees. Finally, watch the garden carefully for the appearance of pests; and when you discover them, begin control treatments immediately.

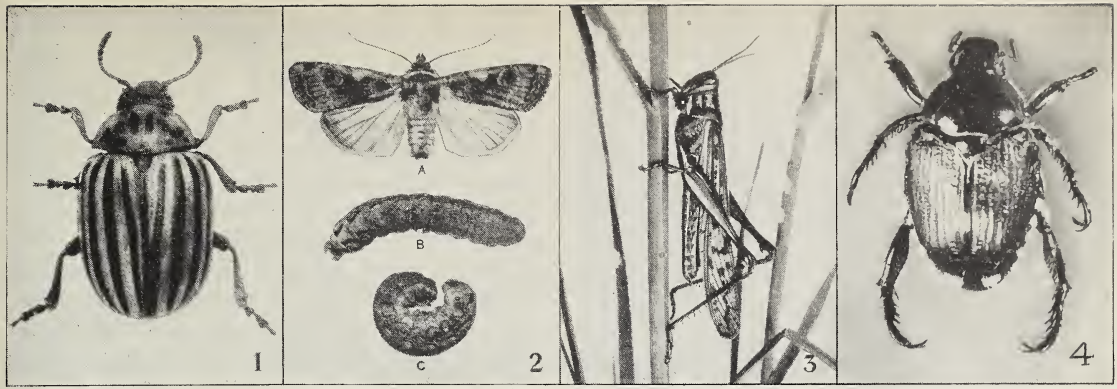
How to control insects. For purposes of control, insects may be divided into two classes, sucking and chewing. The sucking insects, such as aphids (plant lice), leaf hoppers, San Jose scale, and thrips, suck the juice from the leaves and stems of the plant. They must be destroyed by contact sprays, which contain chemicals that destroy the bodies of the insects. The chewing insects feed upon the leaves, stems, and roots of plants and can be de-

Some common sucking insects: from left to right, San Jose scale, aphis, and leaf hoppers



Illinois State Natural History Survey

United States Department of Agriculture, Bureau of Entomology and Plant Quarantine



United States Department of Agriculture, Bureau of Entomology and Plant Quarantine

Some common biting insects: (1) adult Colorado potato beetle; (2) stages in the life cycle of the spotted cutworm: (*A*) moth, (*B*) larva extended, (*C*) larva curled up; (3) grasshopper; (4) male Japanese beetle

stroyed by sprays which render what they feed on poisonous to them. Some of the common chewing insects found in the garden are caterpillars, beetles, slugs, grasshoppers, cutworms, wireworms, grubs, and maggots.

Both types of insects can often be controlled by directing a strong stream of water on the plants, especially trees and shrubs, several times a day. There are several sprays which are effective in the control of these insects.

Sucking insects are best exterminated by the use of nicotine sulfate. A solution is made by adding from one to two teaspoonfuls of 40 per cent nicotine sulfate to a gallon of water to which is added a good soap, such as potash fish-oil soap. Solutions of rotenone and pyrethrum are sometimes used, but neither is as effective as nicotine sulfate.

When large quantities of spraying solution are necessary, as for spraying trees, kerosene emulsion and lime-sulfur are used. They are more economical than nicotine sulfate, but their use may result in the burning of foliage. Kerosene emulsion is a mixture of hard soap, hot water, and kerosene. Lime-sulfur is a mixture of quicklime, sulfur, and water.

Chewing insects may be controlled by spraying the plants with a solution of lead arsenate or Paris green. Both these poisonous insecticides may be either dusted on the plant or made into solutions and sprayed on. Solutions of lead arsenate ($Pb_3(AsO_4)_2$) may be made by dissolving one ounce of the powder and one ounce of soap in one and a half gallons of water. A solution of Paris green ($3\,Cu(AsO_2)_2 \cdot Cu(C_2H_3O_2)_2$) may be prepared by dissolving one-half ounce of Paris green and one ounce of quicklime in three gallons of water. *Remember that both these chemicals are extremely poisonous and should be handled and used with extreme care.*

The control of plant diseases. There are certain kinds of plants which do not have leaves, stems, roots, or flowers and depend upon other plants or animals for their food. Such plants are called fungi. There are many helpful fungi, but there are also some harmful ones. Those which are harmful frequently attack garden plants and destroy them. Such fungus diseases as rusts, smuts, mildews, scabs, and molds are very injurious to plants and require careful methods of control.

The most widely used fungicide is Bordeaux mixture. The mixture may be prepared by dissolving one ounce of powdered copper sulfate and one ounce of lime in three quarts of water. Most fungus diseases of plants yield to the application of Bordeaux mixture. Another fungicide which is being used more frequently than Bordeaux mixture is copper-lime dust. This mixture is usually dusted upon the infected area of the plant.

Combination sprays. It is now possible to buy sprays which act both as a fungicide and as an insecticide. Such sprays usually contain a fungicide, such as lime-sulfur, and an insecticide, such as lead arsenate, mixed together.

Application of sprays. It does not pay to buy a hand sprayer which is too cheap. Those made of

Extension Service, United States Department of Agriculture

Farm woman in Texas dusting her garden peas as a protection against insects

sheet steel coated with tin rust easily. If you have much spraying to do, it is best to buy a knapsack sprayer.

Recently a new method of applying sprays has been devised. The fungicide or insecticide in the form of a cylindrical cartridge is placed in a hollow cylinder with a spray nozzle on one end and a hose attachment on the other end. This device is attached to the garden hose, and the water, when it is turned on, dissolves the chemical, which comes out of the nozzle in a fine mist. Such a method of spraying is convenient.

The eradication of ants. Ants can best be controlled by destroying them in their nests. This can be done by the use of carbon disulfide (CS_2) or calcium cyanide ($Ca(CN)_2$). The best method to employ when carbon disulfide is used is to pour a tablespoonful of the liquid into the hole of a nest and then cover it with a can. This should be done on a warm sunny day. The heat of the sun causes the CS_2 to vaporize; and since the fumes are heavy, they sink to the bottom of the nest, killing all the ants. This should be repeated in about two weeks to kill the newly hatched young ants.

When calcium cyanide is used, the hole of the nest is enlarged with a rod or screw-driver to a depth of about six inches, and the cyanide powder is placed in the bottom of the hole. The hole is then packed with dirt. The calcium cyanide reacts with the moisture of the soil to form hydrocyanic acid gas (HCN), which destroys the ants:

$$Ca(CN)_2 + 2\,HOH \longrightarrow Ca(OH)_2 + 2\,HCN$$

The control of weeds. Weeds are best controlled by cultivation. If they are removed as fast as they grow, the garden will be kept free of them. However, the lawn cannot be cultivated. It is, therefore, necessary to use other methods of keeping the lawn free of dandelions, plantain, and other weed pests. If such weeds are dug so that most of the root is taken out, they will finally disappear. This necessitates a great amount of hard work and constant attention. Perhaps the best method is to put several drops of creosote from an oil can on the crown of the weed. This will cause the weed to dry up and die. Barnyard manure is often responsible for weeds in the lawn and garden. Weeds should never be allowed to go to seed.

EXERCISES

1. How may sucking insects be exterminated?
2. What substances are used to control chewing insects?
3. What precautions should be taken to have a weed-free and pest-free garden?
4. What is one common insect pest? How may your garden be kept free from this pest?
5. What are fungi? How are they controlled?
6. Describe how sprays should be applied.
7. How may ants be eradicated?
8. How may the growth of weeds be controlled in your lawn?

Repeated applications of cyanide will rid a lawn or garden of ants

Problem 5. How are plants grown without soil?

Chemical gardening growing in importance. Chemical gardening, or the soilless culture of plants, has been advertised widely during the past few years. Although it has been in various stages of experimentation since 1860, Dr. William F. Gericke of the University of California was the first, in 1929, to devise methods of making chemi-culture a commercial enterprise. Today thousands of people are engaged in chemical gardening; some are following it as a hobby, and others are pursuing it commercially. Those who dabble in hydroponics, as Dr. Gericke termed it, are finding it interesting, instructive, and satisfying.

What is chemical gardening? When plants are grown in solutions made of water and commercially prepared nutrients, which are identical with those supplied by the soil, the process is called chemical gardening, chemi-culture, soilless culture, or hydroponics.

What are the advantages of soilless culture? The soilless culture of plants has many advantages. Some of them are

1. The cost of the chemicals is less than the cost of adding fertilizers to soil.
2. The culture can be carried on in the home without much mess.
3. Better plants can be grown. They grow larger and yield larger fruits and flowers.
4. Insect pests and diseases which come from the soil can be controlled.
5. The food produced is of better quality, has higher mineral content, and a better color.
6. Foods can be grown everywhere, in or out of season.
7. Generally, larger yields can be obtained than in soil culture.
8. Several crops can be grown during one year.

How can one successfully engage in chemical gardening? It is first necessary for the chemi-culture hobbyist to read as much material on the subject as is available. The directions given here will not be complete in any sense of the word. However, the information will be sufficient for a start.

The *tank* may be of any size, depending on how many plants you want to grow. It can be of wood, metal, enamelware, glass, or pottery. Wood and metal tanks should be given a heavy inside coating of asphaltum. Glass must be covered on the outside with dark paint to exclude the light.

Berenice Abbott

The illustration above shows nasturtium plants being grown in a solution made of water and commercially prepared nutrients. From the dense growth of the plants one can judge the possibilities of chemical gardening, or soilless culture

Next, a *wire tray* should be fitted into the top of the container at a depth of three or four inches from the top. This should be firmly secured to the top edge of the container to withstand the weight of the plant and the bedding. The wire should have a mesh of from one half to two thirds of an inch.

The *nutrient solution* may be made up according to the following formula:

United States Department of Agriculture Formula

Calcium nitrate	118 grams, or 4 ounces
Magnesium sulfate	49 grams, or 1⅔ ounces
Potassium dihydrogen phosphate	29 grams, or 1 ounce

Prepare a stock solution by dissolving each chemical separately in a liter of water. For the tank solution, use 10 cubic centimeters of each stock solution in each liter of water placed in the tank.

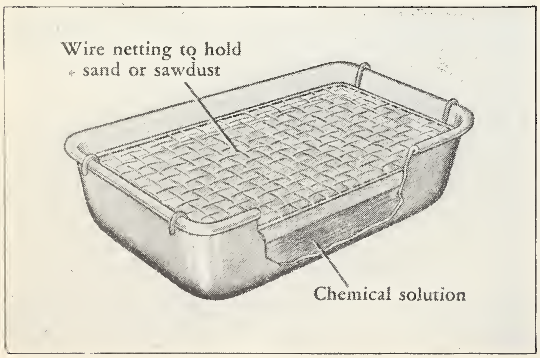
Germination of seeds. The seeds may be germinated in the wire tray in the tank, above the nutrient solution, or in soil or sand. If germination is carried on in the tray, the nutrient solution in the tank must be kept at a level such that it will contact the bedding in the tray. The bedding may be made by placing a thin layer of glass wool on the wire screen and a two-inch layer of sterile sand on the wool. The seeds may then be sown in the sand. It is important that the sand be sterile. It is advisable to wash it first with sulfuric acid and then with a copious amount of water. Some chemi-culturists heat the sand after it is washed.

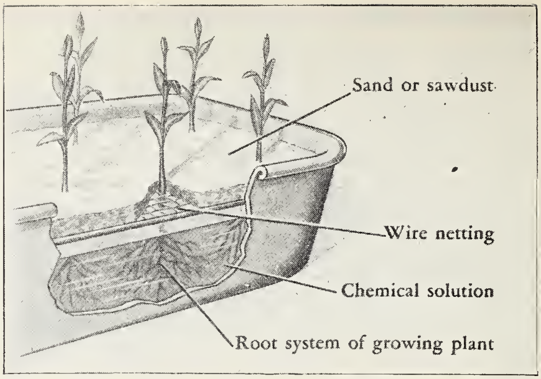
Many who engage in chemical gardening prefer to germinate the seeds in soil or sand and transplant the seedlings to the bedding.

As the roots reach downward in the tank, the level of the nutrient solution should be lowered.

Aeration. It is essential that oxygen be present in the solution because the roots of the plants require it while growing and also because it oxidizes the impurities eliminated by the plant as it grows. For these reasons, daily aeration of the solution is essential. For home chemi-culture, the solution may be aerated (1) by vigorously stirring the solution every day, (2) by using an air pump with an inner-tube valve screwed in the end of the hose so that the solution cannot be sucked into the pump, or (3) by using a syringe.

A chemical-garden tank





The germination of seeds in the tray of a chemical-garden tank

Caring for the growing plants. It is advisable to place the tank where the growing plants will receive a maximum of sunlight. If the plants grow tall, it will be necessary to devise some type of support. If the plants grow flowers which produce fruits or vegetables, cross-pollination is usually secured with a feather. The solution should be changed about every three weeks.

EXERCISES

1. What is the science of hydroponics?
2. What advantages does chemical gardening have over soil gardening?
3. Describe the methods of soilless gardening.
4. How are the elements which are needed only in small amounts provided in soilless gardening?
5. How is oxygen supplied to the roots of growing plants in a chemical tank?
6. Examine the formulas of the solutions used in chemical gardening and determine what element must be provided in the greatest amount.

PROBLEMS FOR FURTHER STUDY

1. How can common insects, fungus diseases, and weeds of the garden be identified?
2. What is the carbon dioxide–oxygen cycle?
3. What is the nitrogen cycle?
4. How can garden seeds be selected intelligently?
5. How is nitrogen of the air utilized by plants?
6. How may one pursue sand chemi-culture as a hobby?
7. What commercial use is being made of chemical gardening?

8. What are the ingredients present in the commercial fertilizers sold in your community?

9. How may gophers be eradicated from the garden or lawn?

10. When and how should shrubs, trees, and vines be pruned?

11. How would you artistically landscape your home?

12. Is the soil in your home garden acidic or basic?

UNIT EXERCISES

The statements which follow are incomplete. On a separate sheet of paper write whatever is necessary to complete each statement correctly. Do not write in this book.

1. For the making of food, plants secure --(?)-- from the air and --(?)-- from the soil.

2. $C_{55}H_{72}O_5N_4Mg$ is the formula for --(?)--, a substance found in green plants.

3. The process of uniting CO_2 and H_2O in the leaves of a plant, in the presence of sunlight, is known as --(?)--.

4. $6\ CO_2 + 6\ H_2O \xrightarrow{\text{sunlight}}$ --(?)-- + --(?)--.

5. Soil is a mixture of disintegrated --(?)-- and --(?)--.

6. Five of the ten important elements necessary for plant growth are --(?)--, --(?)--, --(?)--, --(?)--, and --(?)--.

7. Chemical compounds in the soil must be in --(?)-- form to be usable by plants.

8. When crops are grown and harvested from a particular soil uninterruptedly, the growth elements in the soil are gradually --(?)--.

9. Manure is good for soil because it provides --(?)-- as well as valuable minerals.

10. Some commercial fertilizers are obtained from the nitrate beds of --(?)--.

11. $N_2 +$ --(?)-- $H_2 \longrightarrow$ --(?)--.

12. The equation of No. 11 represents the --(?)-- process of obtaining nitrogen from the air and making it into a usable compound.

13. By passing the product of the reaction shown in No. 11 into sulfuric acid, one can make a fertilizer, --(?)--.

14. $CaC_2 + N_2 \longrightarrow CaCN_2 + C$ is the equation showing the --(?)-- process for fixing N_2.

15. $Ca_3(PO_4)_2 + 2\ H_2SO_4 \longrightarrow 2\ CaSO_4 +$ --(?)--.

16. The names of the compounds expressed in the equation of No. 15 are --(?)--, --(?)--, --(?)--, and --(?)--.

17. Potassium salts are obtained from dried-up --(?)-- and seaweed.

18. --(?)-- is a garden plant which does well in a slightly acid soil.

19. Plant hormones stimulate --(?)-- growth of plants.

20. The addition of --(?)-- to soil decreases the acidity.

21. Soil from your garden may be tested at the --(?)--.

22. Sucking insects must be destroyed by a chemical which attacks the --(?)-- of the insect.

23. Chewing insects may be destroyed by a poisonous spray applied to the --(?)-- of the plant.

24. A good chemical spray to use against sucking insects is --(?)--.

25. $3\ Cu(AsO_2)_2 \cdot Cu(C_2H_3O_2)_2$ is commonly called --(?)--.

26. Bordeaux mixture may be made by dissolving one ounce of --(?)-- and one ounce of --(?)-- in three quarts of water.

27. The best ant poison is --(?)-- or --(?)--.

28. A few drops of --(?)-- placed on the crown of a weed will cause it to dry up and die.

29. The growing of plants and flowers without soil is known as --(?)--.

30. The *p*H value of soil which is neither acidic nor basic is --(?)--.

31. The process of adding --(?)-- to the solution of a chemical garden is known as aeration.

REFERENCES FOR FURTHER READING

CHAMBERLAIN, JOSEPH S. *Chemistry in Agriculture.* The Chemical Foundation, Inc., New York, 1926.

CONNORS, CHARLES H., and TIEDJENS, VICTOR A. *Chemical Gardening for the Amateur.* Wm. H. Wise & Company, New York, 1939.

GRIM, JAMES S. *Introduction to Agriculture.* Allyn & Bacon, New York, 1935.

MATLIN, D. R. *Growing Plants without Soil.* Chemical Publishing Company, Inc., New York, 1940.

TRANSEAU, EDGAR NELSON. *Science of Plant Life.* World Book Company, Yonkers-on-Hudson, New York, 1936.

WESCOTT, CYNTHIA. *The Plant Doctor.* Frederick A. Stokes Company, New York, 1937.

The City Home Garden, United States Department of Agriculture Bulletin No. 1044, Washington, D.C., 1935.

Diseases and Insects of Garden Vegetables, United States Department of Agriculture Bulletin No. 1371, Washington, D.C.

Planting and Care of Lawns, United States Department of Agriculture Bulletin No. 1677, Washington, D.C., 1935.

Denver Water Department

Aerating water at the Marston Lake Filter Plant,
Denver, Colorado

PART IV

CHEMISTRY OF THE COMMUNITY

UNIT 29

The Chemistry of Water Purification

An important factor in the lowering of the death rate and in the decreasing amount of illness has been the realization by the citizens of urban centers and rural areas of the importance of an abundant supply of pure water for domestic purposes.

Cities have learned through bitter experience that water purification is necessary if the health of their citizens is to be safeguarded. It took a number of serious epidemics of typhoid, cholera, and dysentery to awaken the people to the dangers of impure water.

Before man settled this country, the streams were clear and unpolluted. The water from springs was pure and refreshing. When man first came into these regions, there was little danger from the use of this water in its natural state. However, as the country became settled with man and his domestic animals, the water he used became contaminated, and disease was spread. Today it is exceedingly dangerous for campers, picnickers, or anyone to drink water from streams or springs, even though it may appear to be clear and pure. Many people believe that clear water is pure water. As a matter of fact, turbidity, or cloudiness, of water is no indication of its impurity. The turbidity may be due to harmless inorganic sediment. Dangerous germs which cause disease are invisible and do not settle out of water like mud. It is quite possible for the clear water of springs and streams to contain disease-producing microorganisms, and it should not be consumed without purification.

The practice of dumping garbage and sewage into streams by cities and villages has caused the once-pure streams to become polluted. Disease is spread to cities located downstream by the use of this contaminated water if it is not purified. Maps showing the number and location of cases of disease due to the use of impure water indicate that such diseases follow the courses of rivers and are most prevalent just below large cities. The reduction of disease due to impure water has been brought about largely by the following factors: (1) the purification of water by cities and villages; (2) the proper disposal of sewage; (3) the care which rural dwellers exercise in ensuring a safe water supply; (4) the caution exercised by campers, picnickers, and travelers in the selection and purification of the water they drink. You cannot be too careful about the water you drink.

PURPOSES TO BE ACHIEVED

1. To realize the relationship between pure water and good health.
2. To see that the furnishing of an ample supply of pure water to its citizens and the safeguarding of its purity are functions of the government of a municipality.
3. To learn how the impurities of water may be removed.
4. To learn how to purify water in emergency situations.

PROBLEMS TO BE SOLVED

1. What is the source of the water supply for city and rural dwellers?
2. What are the common impurities which contaminate water?
3. How is water purified?

Problem 1. What is the source of the water supply for city and rural dwellers?

Cities need an abundant supply of water. Among the factors which the managements of many industries investigate before deciding to establish their plants in a particular city are the abundance and cost of an ample supply of water necessary for the operation of their plants. Laundries, steel mills, power plants, petroleum refineries, packing houses, and, in fact, most modern industrial plants require a great deal of water. It is necessary, then, for every city to provide an ample supply of water for consumption in industrial plants.

The modern city and town or village must maintain and operate a system for collecting and disposing of sewage. This requires a great deal of water. Every city must provide water for adequate protection against fire. Considerable water is also used for sprinkling and washing streets and for irrigating parks.

The domestic water needs of every city are great. The homeowner uses large quantities of water for many purposes other than for drinking and bathing. The washing of clothes, dishes, cars, and sidewalks requires a great deal of water. Many homeowners use large quantities of water for watering lawns, gardens, trees, and shrubbery. In many cities the average daily consumption for each person is 200 gallons of water.

Where do cities obtain their water? So serious is the problem of securing an adequate supply of water that many cities go miles away to obtain their water. Los Angeles transports its water through a great aqueduct for 223 miles from the distant Sierra Nevada.

New York goes over a hundred miles to the Catskill Mountains for its main supply of water. The water is transported through a large tunnel aqueduct which burrows through mountains of solid stone and far below the beds of rivers. Five hundred million gallons of water a day flow through this tunnel. The water is run into a large reservoir on the outskirts of the city. After purification, it is carried by another tunnel deep beneath the streets and tall buildings to the various parts of the city. In some places it is 750 feet below the surface of the ground. Basements of large buildings would have to be about sixty stories deep to be on a level with this water tunnel. The water is brought up to the surface system by large iron pipes.

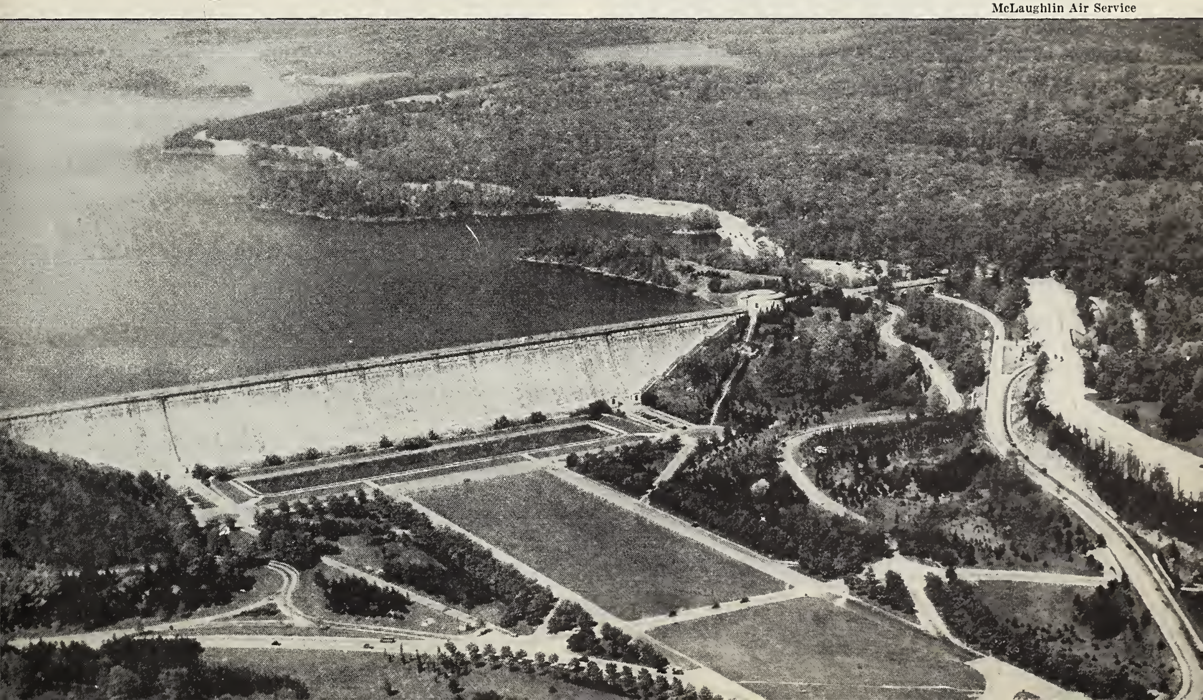
Some large cities are located near large lakes, from which they get their supply of water. Chicago, Cleveland, Grand Rapids, and Detroit obtain their water from the Great Lakes. Intakes are located several miles out in the lake to ensure getting pure and clear water. Even this water must be purified before consumption.

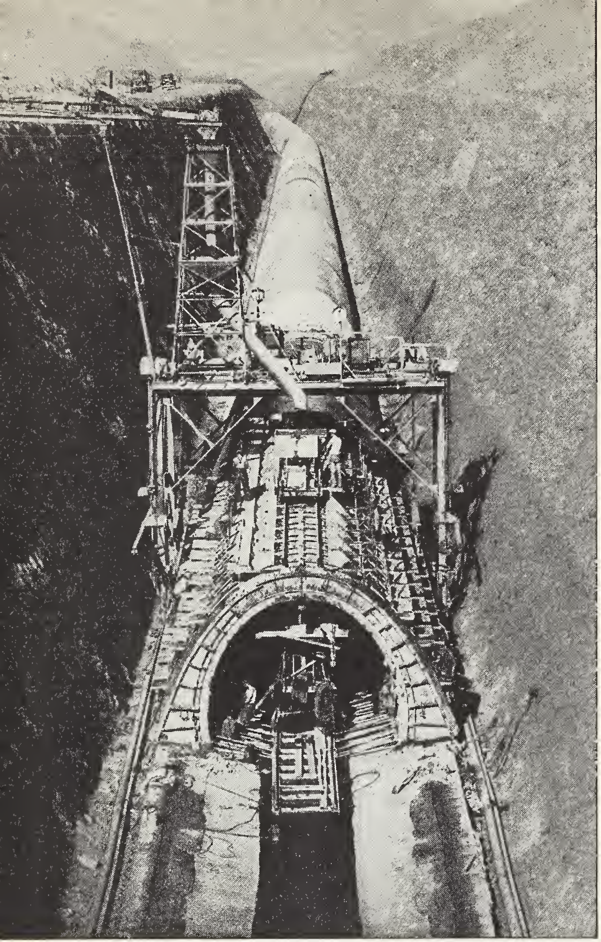
Other cities, such as St. Louis and Cincinnati, obtain their water from large rivers. Some cities, such as Fort Worth, Texas, must dam up smaller streams and impound the needed water in reservoirs.

Denver tunnels through the heart of the Rocky Mountains to bring some of its water from the other

The Kensico reservoir, from which New York City gets part of its water

McLaughlin Air Service





The Metropolitan Water District of Southern California

This great aqueduct was recently completed and now carries water from the Colorado River to the city of Los Angeles

side of the continental divide. It also dams up numerous mountain streams to impound the water which comes from the melting snow in the spring of the year.

Many bitter controversies have been waged between cities anxious to preserve sources of water for future needs. Denver was forced to bring a large amount of water from the western slope of the Rocky Mountains to protect its water rights there; otherwise it would have forfeited its claim to this water to certain California cities hundreds of miles away.

Some smaller cities, such as Carlsbad, New Mexico, obtain their water from deep wells. Most of these smaller cities and most towns and villages operate a municipal water system, but some are still supplied by private concerns.

Bottled water. In almost every city there are privately owned concerns which supply pure, soft water in large bottles for drinking purposes. This service often includes the furnishing of cooling devices or ice. These companies should be required to furnish a monthly certificate of analysis showing the purity of the water. Sanitary methods of bottling the water should be maintained at all times.

Rural water supply. The securing of a safe supply of water is often a serious problem with suburban and rural residents. In most cases, the water is obtained from wells by hand pumps, power pumps, windmills, or rope-drawn buckets. The depths of these wells vary from a few feet to hundreds of feet.

Often a farmer may have a spring and a springhouse on his place, and he secures his domestic water from this source. Others secure water from small or large streams.

In some rural sections, particularly the more arid ones, rainwater is collected from the roofs of houses and run into cisterns. These may be made of metal or wood and located above the ground, or made of concrete and placed below the ground.

Many rural and suburban dwellers have water tanks, or reservoirs, placed high on platforms or in roof attics to ensure a satisfactory water pressure. Sometimes two or more near-by families maintain a co-operative water-supply system.

EXERCISES

1. What is the relationship between the growth of population in a community and the purity of the water in the streams of that community?

2. Why should you study the chemistry of water purification?

3. Why is it of the utmost importance that cities have an abundant supply of pure water?

4. What are some of the problems that cities have to solve to obtain pure water?

5. What problems do rural people meet in obtaining pure water?

Problem 2. What are the common impurities which contaminate water?

What happens to rain water? Rain water is almost pure, particularly in rural areas and mountains away from the dust and smoke of cities. When it falls to the earth, it runs off as surface water, soaks into the ground, or evaporates. The water which runs off goes from smaller streams to larger streams and finally to the ocean. Water which soaks into the ground is absorbed by vegetation, is held in the soil, or sinks downward until it reaches impervious rock. The water which reaches the impervious stratum accumulates and forms subsurface, or ground, water. The upper surface of this water forms what is called the water table. The ground water moves toward lower levels with the slope of the land. If the stratum of rock is exposed to the ground surface at a lower level, springs may occur. If wells are dug to the water table, water will be found.

Gases dissolved in natural water. As rain falls through the air or as water flows rapidly in streams and over falls, it absorbs oxygen from the air. This makes the water palatable and aids in purifying it by oxidizing the organic matter, which is food for bacteria and other microorganisms. Water which is motionless loses its oxygen and becomes stagnant and unfit for use.

Water which flows or percolates into the ground through decaying leaves and vegetable matter often absorbs carbon dioxide gas (CO_2). Sometimes the carbon dioxide gas is held in solution by pressure in the subsurface water. When the pressure is released as the water emerges in springs or wells, the carbon dioxide gas may effervesce from the natural carbonated water. In Manitou Springs, Colorado, carbonated beverages are made from this natural carbonated water.

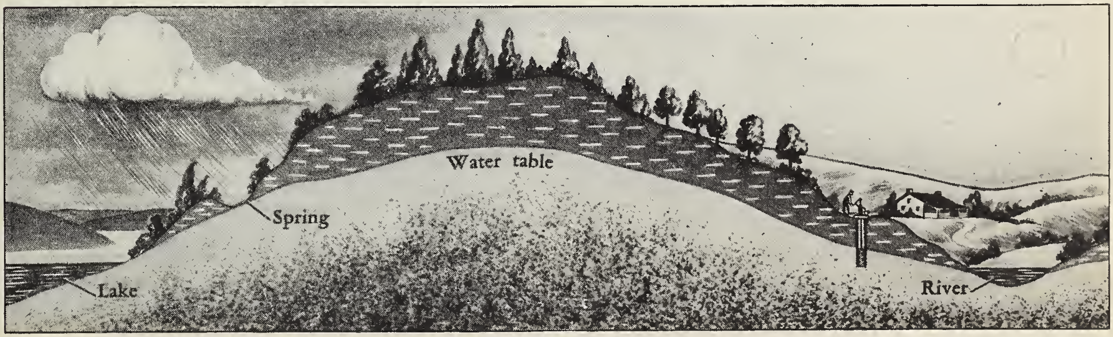
In some areas, subsurface water passes through sulfur deposits and absorbs some hydrogen sulfide. Sulfur-water springs and wells have no medicinal value, though health resorts sometimes make extravagant curative claims for the water.

Organic material and microorganisms in natural water. Water which seeps through the ground or which runs off as surface water into streams becomes exposed to many kinds of decaying organic matter and microorganisms. Microorganisms, such as algae and fungi, harmless bacteria, and disease germs, may contaminate the water. Some of these may discolor the water and impart a disagreeable taste to it, but others may be present in water without discoloring it or imparting an unpleasant taste or odor.

A clear cool mountain spring may contain *Bacillus coli* and other disease-producing germs from human excreta or decaying organic matter from dead animals.

Streams become polluted from the organic waste materials of cities and farms. Subsurface water may become contaminated by water seeping into it from stables and outhouses. Typhoid, the paratyphoids, dysentery, cholera, and other intestinal diseases may result from the consumption of such water if it is not purified.

Mineral matter in water. All natural waters contain dissolved mineral matter and often small suspended particles of sand and dirt. Mineral matter is dissolved by the water as it percolates through soil and rock. The salts in solution are sodium chlo-



The water which falls as rain will either run off to streams or be absorbed by the soil. That which is absorbed by the soil either is used by plants, comes back to the surface by capillary action, and is evaporated, or sinks to the water table, where it feeds springs and wells[1]

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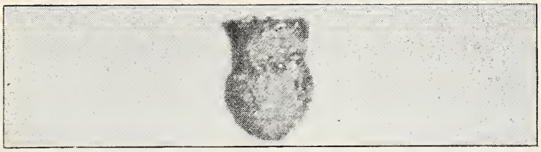
[1] Reproduced from Powers, Neuner, Bruner, Bradley's *Exploring Our World*, Ginn and Company.

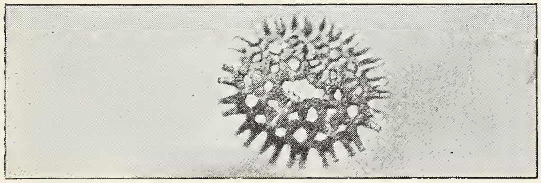
Microorganisms Found in Water

All photographs on this page are by George J. Turre.



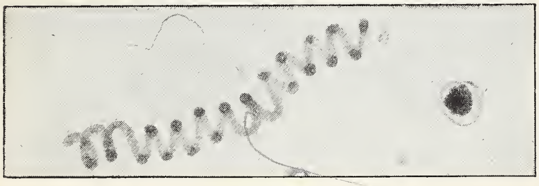
Codonella

Codonella is one of the Protozoa. It is a free-swimming organism, bell-shaped, brownish in color, and covered with fine cilia. Its presence in water imparts a fishy taste and odor



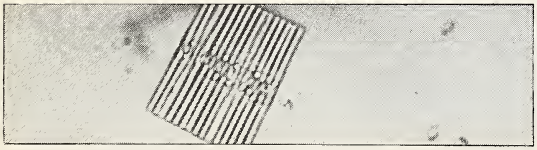
Pediastrum (Gear Wheel)

Pediastrum belongs to the Chlorophyceae group. Water which contains it has a grassy or fishy smell



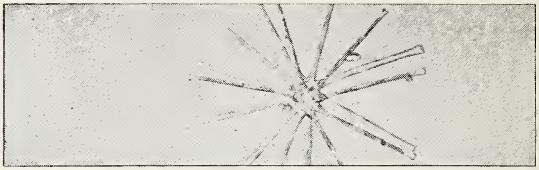
Anabaena

The *Anabaena* is one of the Cyanophyceae group of blue-green algae. It flourishes in fairly warm water, and occurs in several forms, the most common of which (flos-aquae) is shown in this illustration. It is blue-green or brownish in color, is free-floating, and resembles a string of beads.



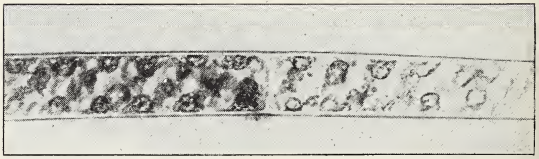
Synedra

This comb-shaped organism is one of the diatom group. It gives an earthy taste and odor to water



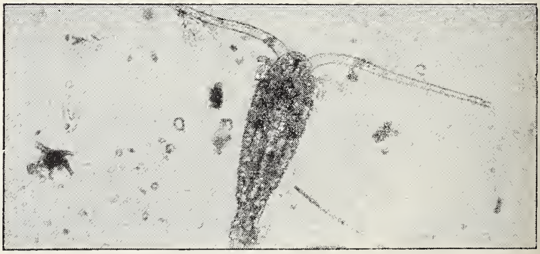
Asterionella (Little Star)

This is one of the diatom group. It is shown here in the process of multiplication. This organism in small amounts gives water a geranium-like odor; in larger amounts it gives a fishy odor and taste. It is especially abundant in the spring and fall. It is one of the most common of the algae



Spirogyra

Spirogyra belongs to the group of green algae. These algae are made up of thin filaments which float on the water. They flourish at a temperature slightly lower than that at which algae of the blue-green group thrive. They give a grassy taste and smell to water in which they are present. They are abundant in midsummer



Cyclops

The *Cyclops*, so named because of its large single eye, is one of the Crustacea group. It is prevalent in the spring and fall, is visible to the naked eye, and moves about with a jerky motion. Its presence in water imparts a fishy taste and smell.

ride, magnesium and calcium bicarbonates and sulfates, lime, iron salts, and sometimes lithia and radium salts. Occasionally water percolates deep into the earth and comes in contact with hot rock. When this hot water emerges in springs, it usually contains a great deal of dissolved mineral matter. As it cools, it deposits some of this mineral matter as a formation of carbonates and sulfates about the spring. Many of these hot springs have been exploited commercially by health resorts for their supposedly curative powers.

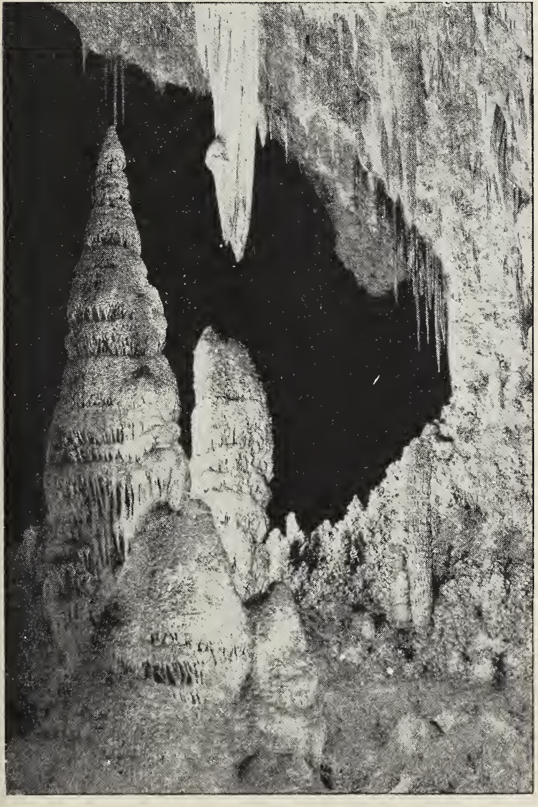
How are caves formed? When water containing CO_2 comes in contact with limestone, it reacts with the rock, slowly dissolving it as soluble calcium bicarbonate ($Ca(HCO_3)_2$). This eventually leaves large crevices and caves in the rock, sometimes far below the surface. The reaction may be expressed by these equations:

$$H_2O + CO_2 \longrightarrow H_2CO_3$$
$$H_2CO_3 + CaCO_3 \longrightarrow Ca(HCO_3)_2$$

Sometimes the water, with its calcium bicarbonate, drips from the roofs of the caves and gives up its carbon dioxide, leaving a deposit of insoluble $CaCO_3$. These deposits grow in size and form sharp-pointed stalactites, which hang from the roof, or stalagmites, which are built up from drippings on the floor. Large caves, such as the Carlsbad Caverns in New Mexico and Mammoth Cave in Kentucky, have been formed by these processes.

Chinese Temple in the Big Room of the Carlsbad Caverns. Beautiful formations such as these are made by the gradual precipitation of calcium salts as the water evaporates

United States Department of the Interior



What is hard water? Not all water which contains mineral matter is hard. Hard water is water containing mineral matter which reacts with soap to form an insoluble sticky curd. Hard water contains calcium and magnesium chlorides, bicarbonates, and sulfates. Water containing only the bicarbonates is called temporary hard water because it gives up the mineral matter as carbonates upon heating:

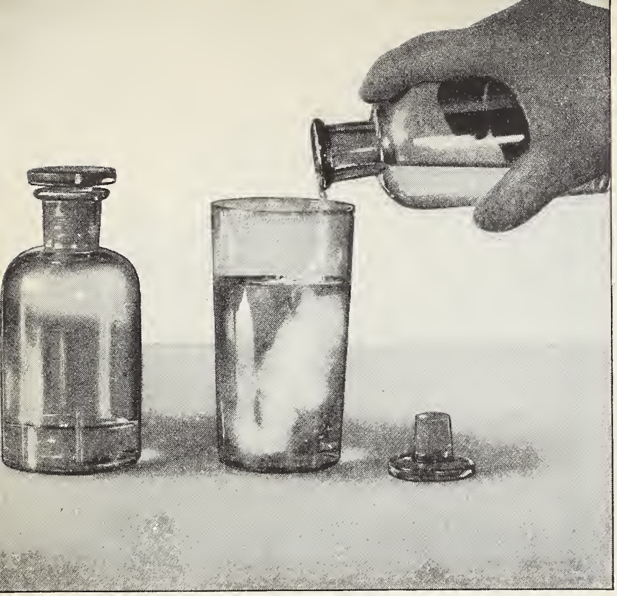
$$Ca(HCO_3)_2 + \text{heat} \longrightarrow CaCO_3\downarrow + CO_2\uparrow + H_2O$$

Water containing soluble calcium and magnesium chlorides and calcium and magnesium sulfates is difficult to soften and is called permanently hard water. The calcium and magnesium ions react with soap, displacing the sodium ion to form an insoluble soap curd:

$$\underset{\text{hard water}}{CaCl_2} + \underset{\text{soap}}{2\ NaC_{17}H_{35}COO} \longrightarrow \underset{\text{salt}}{2\ NaCl} + \underset{\text{insoluble soap curd}}{Ca(C_{17}H_{35}COO)_2}$$

Hard water is sometimes called alkali water, since it occurs most frequently in alkali-earth regions.

What are goiter regions? A small amount of iodine is necessary for the proper functioning of the thyroid gland. This iodine is obtained from the food we eat and the water we drink. Sea foods are particularly rich in iodine, and most natural waters contain enough iodine to supply this need. However, in certain interior regions there is a deficiency of iodine in the natural water. When the body does not receive enough iodine, the thyroid gland may become enlarged; this condition is called goiter.



A soap solution is being added to hard water containing magnesium and calcium salts. The white precipitate which forms is insoluble calcium and magnesium stearate

Areas with water containing little iodine are sometimes called goiter regions.

Iodized salt, containing a small amount of sodium iodide, is sold in these regions to make up for this deficiency. Some cities add small amounts of sodium iodide to the city water to correct this deficiency.

Fluorides and mottled teeth. When natural water contains more than 0.9 part of fluoride salts per million parts of water, it often causes mottling of the tooth enamel of children who drink it. The injury occurs only during the formation and growth of teeth. There is no remedy for this condition. The only safeguard is for children in these regions to drink rain water or water from a fluorine-free source. There is no danger after the permanent teeth have been formed.

EXERCISES

1. Why is rain water pure when it falls in isolated regions?

2. What gases are dissolved in natural water?

3. What microorganisms may contaminate natural water? How do such organisms get into the water?

4. Describe the mineral substances which are found in natural water.

5. What are the conditions which exist when underground caves are formed?

6. Describe the formation of caves such as the Carlsbad Caverns.

7. Explain how hard water affects soap.

8. What is a goiter region? Why does such a region exist?

9. What causes the mottled teeth of children living in some communities?

Problem 3. How is water purified?

Characteristics of water. The characteristics of water which are of concern in its purification may be classed as physical, chemical, microscopical, and bacteriological.

The physical characteristics include turbidity, color, taste, odor, and temperature. These characteristics in themselves have little effect on the health of persons drinking the water. People naturally prefer water which is clear, colorless, odorless, cool, sparkling, and pleasant-tasting. They drink more of it, and thus their health is benefited. They dislike water which is turbid, colored, unpleasant-tasting, warm, dull, or of foul odor, although it may contain no germs and be quite safe. A person may even turn from a pure but turbid water to a contaminated water with a better appearance.

The chemical characteristics of water include the presence of mineral salts and decomposed organic matter. A chemical analysis of water will show the mineral and organic matter present. In the processes of clarifying and softening water, it is necessary to make certain chemical and physical tests of raw and treated water in order to maintain proper control over the operations. A chemical analysis showing the presence of organic matter indicates a past or present pollution of the water.

Microscopic examination of natural water will show the presence of small plants, such as algae, and animal organisms. These organisms may range in size from those which can be seen only with a microscope to those visible to the unaided eye.

Bacteria which may be present in natural water can only be determined by bacteriological tests. There is an exceedingly large number of bacteria in all natural water. Most of these are harmless. The total number of bacteria per cubic centimeter is determined by the city-water chemist or bacteriologist. Generally this number is of little importance; however, when it becomes excessively high, there is danger that the number of harmful bacteria may be large. It may show that surface water is contaminating the ground-water supplies or storage reservoirs of the city.

A much more important bacteriological test made by water chemists is that for *Bacillus coli.* Bacteria of this kind come from the intestines of human beings and are discharged with the excreta, or feces. They may or may not be harmful. Rarely, if ever, are they found in animals. It is impracticable to test water for specific disease germs, such as typhoid bacteria. However, if the tests show the presence of *Bacillus coli*, safety measures must be exercised, as it indicates that bacteria from human excreta are in the water, and there is danger that disease-producing bacteria may be present.

Ensuring a pure source of water. The most important precaution which a city can exercise in order to ensure an uncontaminated supply of water is to protect the water from pollution at its source.

Chicago protects its water supply in Lake Michigan by prohibiting the dumping of refuse and sewage into the lake. The watershed and lakes which supply Denver with water are policed to make sure that campers and picnickers observe strict sanitary measures. Sanitary rest houses are provided, and garbage receptacles are placed in camp grounds. State boards of health often prohibit the dumping of the sewage and refuse of cities into streams. Storage reservoirs are protected against human contamination, and the public is made conscious of the dangers of a polluted water supply.

Purifying the water of a city. Even though the water supply of a city is protected at its source from contamination, the presence of suspended matter, small plant and animal life, and germs necessitates its purification. The process generally used includes settling, aeration, coagulation, filtration, and sterilization.

Settling basins. The water is pumped or conducted through pipes or aqueducts from the lakes, retaining reservoirs, or rivers into settling basins. As it passes into the intake pipes at these sources, it runs through screens which prevent fish, insects, moss, and debris from entering with the water. The water may remain in the settling basins for one or more days. About 65 per cent of the suspended matter will settle to the bottom of the basins.

Denver Water Department

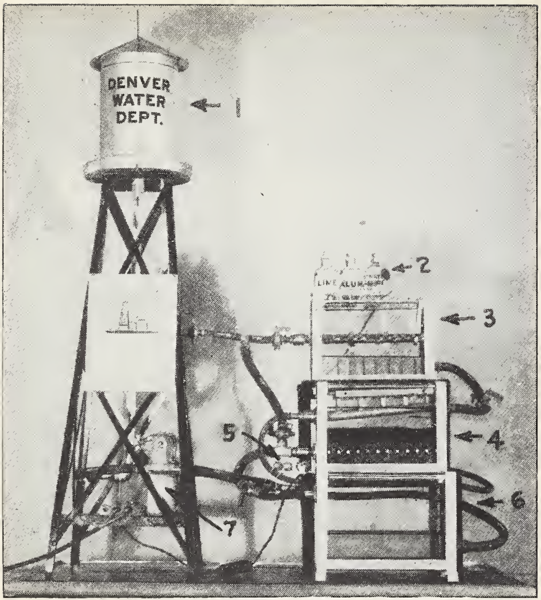
An interior view of the Moffat Rapid Filter Plant, Denver, Colorado. The filter beds are located on each side of the passageway

To prevent the growth of algae and other small plants, a small amount of $CuSO_4$ is added by dragging sacks containing it through the water. About ten pounds per million gallons of water is sufficient.

Aeration. Water may contain some objectionable gases, such as hydrogen sulfide (H_2S), coloring matter, organic matter, and an objectionable taste and odor. These characteristics may be partially counteracted by aeration. This process consists of mixing air with water in one of several ways: (1) by spraying the water into the air from nozzles; (2) by allowing the water to cascade over a series of steps; (3) by passing the water in thin sheets down an inclined plane or dam; (4) by trickling the water through coke.

Aeration makes the water more palatable by the addition of dissolved oxygen. It substitutes oxygen for the other dissolved gases present. Iron, as ferrous compounds, which occur in some subsurface water, is oxidized to insoluble ferric oxide, which is settled or filtered out. Some of the organic matter remaining in the water is oxidized and is thus destroyed as food for bacteria and other microorganisms.

Coagulation. Where the water is very turbid, the suspended matter is further removed by a process called coagulation. When certain chemicals, such as



George J. Turre, Chief Chemist, Denver Water Department

Model of a water-filtration system. (1) Raw-water storage tank. (2) Chemicals used for coagulation (alum and lime). (Activated carbon is used for the removal of taste and odor.) (3) Sedimentation chemical mixing basin and aeration system. (4) Filter unit—anthracite used as a filtering material. (5) Disinfection—chlorine and ammonia treatment. (6) Filtered-water reservoir. (7) Pumps, used to pump filtered water into storage tank

ferrous sulfate or alum (potassium aluminum sulfate), are added to water, they hydrolyze to form an insoluble gelatinous precipitate called floc:

$$\overset{\text{alum}}{2\ \mathrm{KAl(SO_4)_2}} + 6\ \mathrm{HOH} \longrightarrow \overset{\text{floc}}{2\ \mathrm{Al(OH)_3}\downarrow} + \mathrm{K_2SO_4} + 3\ \mathrm{H_2SO_4}$$

Slaked lime ($Ca(OH)_2$) is sometimes added to hasten the formation of the floc.

As the water is pumped from the settling basins, it is mixed with the chemicals in a mixing chamber and allowed to run into coagulating basins. The floc settles quickly to the bottom of the basins as a gelatinous precipitate, carrying with it the greater part of the remaining suspended matter, including a portion of the bacteria. This process usually requires about four hours.

Rapid filters. After the floc has been precipitated in the coagulating basins, the water is run through sand-and-gravel or coal filters. An eighteen-inch layer of graded gravel is placed over drain tiles and covered with about thirty inches of clean sand. In some filtering plants coal is being used instead of sand and gravel. The water flows in over the sand, sinks through to the tiles, and is conveyed to storage reservoirs. A little of the floc forms a gelatinous layer over the sand, and holds by adhesive action about 90 per cent of the microorganisms and nearly all the remaining suspended matter.

Rapid filters are cleaned every twenty-four hours by allowing water to run under pressure in the opposite direction through the gravel and sand. The impurities are carried away with the waste water.

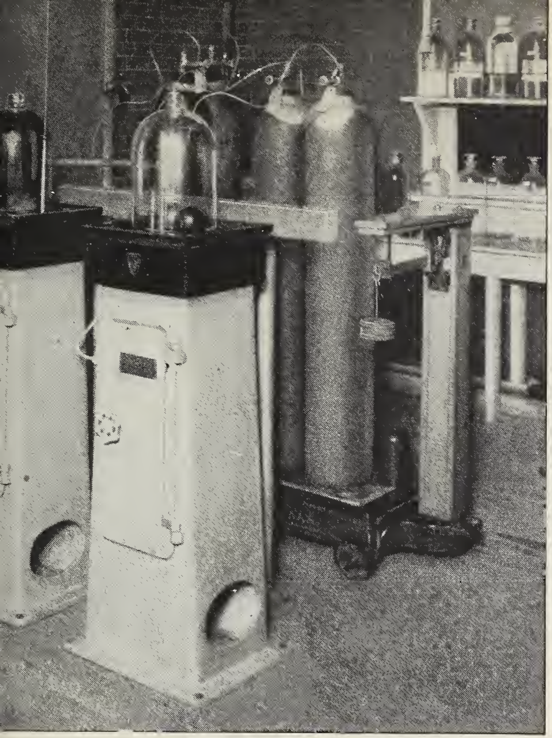
Chlorination. If the water shows the presence of *Bacillus coli* or an excessive number of other microorganisms, chlorine gas is added just before it goes to the city distribution system. This destroys the remaining organisms. The chlorine is run from tanks through small pipes to the conduit pipes. When the chlorine enters the water, it forms hypochlorous acid (HClO) and hydrochloric acid:

$$\mathrm{H_2O} + \mathrm{Cl_2} \longrightarrow \mathrm{HCl} + \mathrm{HClO}$$

The hypochlorous acid is very unstable and breaks down into hydrochloric acid and nascent oxygen. The destruction of the microorganisms is due to the nascent oxygen and to the germicidal effect of the

The chemical laboratory of a large city water department. Eternal vigilance on the part of these men keeps our domestic water free from contamination

Denver Water Department



By means of this apparatus, a small amount of chlorine is added to city water as the final step in its purification. Ammonia is also added, with the chlorine, to prevent the formation of undesirable odor and taste

chlorine and the chlorine compounds which are formed.

A more recent method of chlorination is to add ammonia gas (NH_3) to the water just before admitting the chlorine. This forms a compound known as chloramine. Its reaction may be expressed as follows:

$$2\ NH_3 + Cl_2 \longrightarrow NH_4Cl + \overset{\text{monochloramine}}{NH_2Cl}$$

$$3\ NH_3 + 2\ Cl_2 \longrightarrow 2\ NH_4Cl + \overset{\text{dichloramine}}{NHCl_2}$$

It has the advantage of eliminating the objectionable taste and odor of straight chlorination. The safety factor is higher because chloramine retains its germicidal power for a longer period than chlorine, thus protecting the water in the city mains. It does not, however, kill germs as quickly as chlorine alone.

Other methods of disinfecting water. Ozone (O_3) has been used to kill germs in water. The passage of an electric spark through air may transform some of the oxygen into ozone:

$$3\ O_2 + \text{electricity} \longrightarrow \overset{\text{ozone}}{2\ O_3}$$

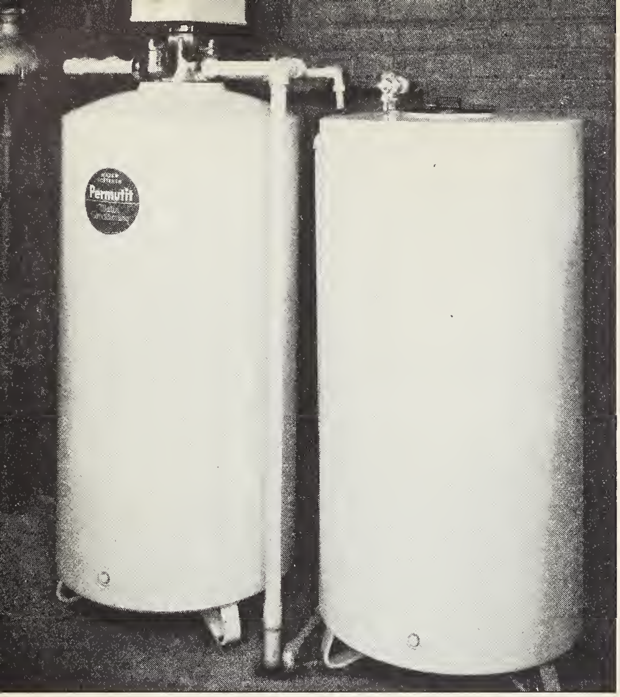
The cost of installing the machines used in this method for purifying water and the operating expense are higher than the cost of chlorination, which fact has limited the use of this method.

Ultraviolet rays have been used to destroy the germs in water systems. These rays have also been used to sterilize soft drinks and bottled water. Some of the steamers on the Great Lakes use this method to purify the water of the lakes for drinking purposes. Ultraviolet rays are generated by mercury-vapor lamps, which are made of quartz tubes through which a current of electricity is conducted by mercury vapor. Water is allowed to flow over these tubes and thus is exposed to the germicidal effect of the rays. This method is frequently used in purifying water in swimming pools. However, most swimming pools use the chlorination process for the sterilization of the water.

Removing objectionable mineral impurities—softening hard water. Many cities have found that the annual saving of soap after the water has been softened more than pays for the chemicals used in the process. A further saving is made because of the fact that soft water does not produce scale in boilers and heating systems.

The hardness of the water is due to the presence of calcium and magnesium ions. These may be

Copper sulfate is added to water in reservoirs to prevent the formation of green algae. This is done by placing lump copper sulfate in sacks and dragging them through the water



Permanently hard water may be softened—that is, the soluble calcium and magnesium salts may be changed to insoluble salts—by being passed through water-softening units such as these

removed by adding sodium carbonate to the alum or ferrous sulfate in the coagulation chamber. Insoluble $CaCO_3$ and $MgCO_3$ are precipitated out along with the floc in the coagulating basin:

$$CaCl_2 + Na_2CO_3 \longrightarrow 2\ NaCl + CaCO_3\downarrow$$

The presence of the NaCl is not objectionable.

Home and laundry softening plants. In regions where the water is very hard, many homes soften their water by the permutite or the zeolite process. These processes employ a complex sodium-aluminum silicate which may be represented by the formula $Na_2O \cdot Al_2O_3 \cdot 2\ SiO_2$. The finely divided permutite or zeolite is placed in a special tank, and the hard water is allowed to flow down through it. The magnesium and calcium ions displace the sodium ions in the insoluble silicate and are removed from the water. The soft water is then ready for use.

$$\begin{aligned} &Na_2O \cdot Al_2O_3 \cdot 2\ SiO_2 + CaCl_2 \\ &\qquad \longrightarrow CaO \cdot Al_2O_3 \cdot 2\ SiO_2 + 2\ NaCl \end{aligned}$$

In time, the permutite will need to be regenerated. This is done by allowing a saturated solution of common salt to run through the calcium permutite, which reverses the reaction and forms the original sodium permutite again.

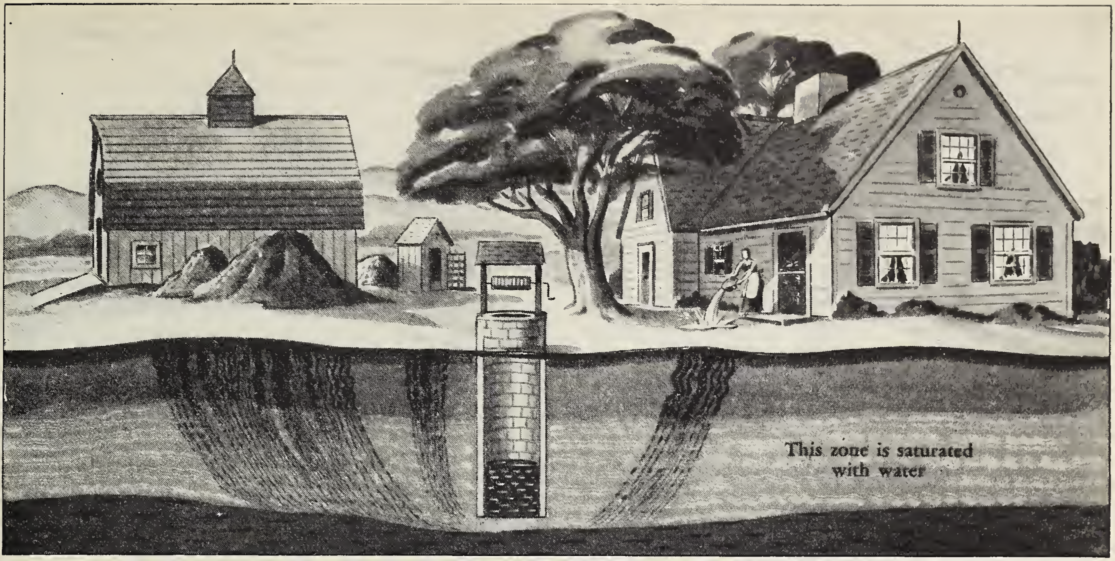
Protecting the water supply on farms. The residents of urban centers have been quicker to realize the importance of providing a pure water supply than people living in rural areas. Since most rural residents obtain their water from wells, the location of wells in reference to the slope of the land and the distance from outhouses and barns is of extreme importance. A well should be located so that there is no danger that the ground water will become contaminated by surface water which may come from such places as outhouses and barns. The well should have a collar which extends several feet into the ground to protect it from surface water during rains. It should have a tightly fitting cover. The old oaken bucket may seem poetic to us now, but it was anything but sanitary. The rope and bucket were handled by many hands, and the water was certain to be contaminated. Pumps are much safer.

Usually the deeper the well, the safer will the water be for human consumption. Water which flows through the earth for a great distance is usually purified by natural filtration.

Cisterns should be covered to keep out insects, especially mosquitoes, rodents, and dust. Charcoal filters make the water clearer but give the persons using them a false feeling of security. The water may be even more contaminated after having run through such filters than before.

Purifying water in emergencies. It is extremely dangerous to drink water from streams or from any questionable source. In cases of emergency, however, any available water must sometimes be used. Boiling water for twenty minutes will completely sterilize it, though it may taste flat. Pouring it from one vessel to another several times will cause some air to be dissolved in it, and thereby its taste will be improved.

Chemicals may be used effectively in sterilizing water. Tablets containing chlorine compounds which may be used for this purpose can be purchased from drugstores. Tincture of iodine, two drops to each quart of water, is recommended in case of emergency. The water should be thoroughly stirred after


This zone is saturated with water

adding the iodine and allowed to stand for thirty minutes. Chlorinated lime and sodium hypochlorite may also be used effectively. The directions for their use are given on the label of the can or bottle.

EXERCISES

1. What are the physical properties of water?
2. What are the chemical properties of water?
3. What microorganisms which may be found in water are harmful?
4. What microorganisms which may be found in water are harmless?
5. In what ways does a large city protect its water supply?
6. Describe the methods of purifying the water for a large city.
7. What is the purpose of aeration in water purification?
8. What is meant by coagulation in the purification process?
9. What purposes do filters serve in the purification of water? Is all filtered water pure?
10. What is pure water?
11. How and why is water chlorinated?
12. What is the purpose of passing ozone through water?
13. How may hard water be softened?
14. Does purification produce soft water? Why or why not?
15. How may water be purified in an emergency?

Shallow wells which furnish water for domestic purposes should be located away from sources of pollution[1]

PROBLEMS FOR FURTHER STUDY

1. What is the source of the water supply for your community or home?
2. What steps are taken to protect it from pollution at its source?
3. Make a study of the processes involved in the purification of the water by your community water plant.
4. Show how the reforestation of cutover areas will improve the purity of public water supplies.
5. What are the common diseases which may be contracted through contaminated water?
6. Describe the dangers to health which may arise from polluted water during flood periods and tell what precautionary measures should be adopted.
7. How should springs be protected against animal pollution and the entrance of surface water?
8. How would you design a spring basin so that people would not have to dip a cup into the water to get a drink?
9. What is the most sanitary method of disposing of the refuse about a camp?
10. When wells are to be cleaned out, why are lighted candles lowered to the bottom before anyone enters to do the cleaning?

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[1] Reproduced from Powers, Neuner, Bruner, Bradley's *Exploring Our World*, Ginn and Company.

11. Why are fish planted in the lakes which supply a city with water?

12. Will the freezing of water kill the harmful germs which may be present?

13. Why does the water of slow-moving streams sometimes taste flat, whereas the water of mountain streams does not?

14. Hard water forms a great deal of boiler scale. Describe how a power plant can soften the water for use in its boilers.

UNIT EXERCISES

On a separate sheet of paper write the word *true* for the statements which are true and the word *false* for those which are false. Rewrite the false statements so that they are true.

1. The pollution of streams is more likely to occur where there are large numbers of people than in thinly populated regions.

2. A city should provide just as pure water for washing streets as for drinking purposes.

3. Water purifies itself when allowed to run down an open stream.

4. Rain water in an isolated region is pure water.

5. The upper surface of subsurface, or ground, water forms the water table.

6. CO_2 is sometimes held in solution under pressure in underground water.

7. A clear cool mountain spring will always be found to furnish pure water.

8. All natural waters contain minerals.

9. The water of many mineral hot springs has special curative properties.

10. Hard water contains the soluble salts of calcium and magnesium.

11. Underground caves are formed only in limestone deposits.

12. Underground caves are formed by the action of carbonic acid upon limestone.

13. $H_2SO_4 + CaCO_3 \longrightarrow CaSO_4 + H_2CO_3$ is an equation which shows how underground caves are formed.

14. Water containing $Ca(HCO_3)_2$ is known as temporary hard water.

15. The curd which forms when soap is put with hard water is an insoluble soap.

16. A goiter region is likely to exist where the ground water has a deficiency of iodine compounds.

17. Iodized salt contains a small percentage of sodium chloride.

18. A mottled appearance of the teeth of children is caused by the presence of iodide salts in the drinking water.

19. All turbid water contains harmful bacteria.

20. The presence of organic material in water indicates a polluted condition.

21. All the bacteria in water are harmful.

22. The presence of *Bacillus coli* in water indicates pollution from human excreta.

23. A settling basin is the first step in the purification of city water.

24. About 65 per cent of the suspended matter will settle out in such a basin as is referred to in No. 23.

25. Aeration helps to purify water by oxidizing some of the bacteria in the water.

26. Potassium aluminum sulfate is added to water to form a floc.

27. The formation of floc is due to electrolysis.

28. The addition of lime to water which has been treated with alum will retard coagulation.

29. $2\,KAl(SO_4)_2 + 6\,HOH \longrightarrow 2\,Al(OH)_3 + K_2SO_4 + 3\,H_2SO_4$ is an equation showing the formation of floc.

30. The filtration of water which has been coagulated with alum will remove most of the bacteria.

31. All bacteria remaining in water after filtration may be killed by the addition of chlorine gas.

32. Ammonia gas is added to water immediately after the chlorine.

33. When ammonia and chlorine are both added to water, chloramine is formed.

34. If water of questioned purity is brought to a boil, it may be drunk with safety.

35. In rural homes the location of the well in relation to the slope of the land is a fact which it is important to take into consideration.

REFERENCES FOR FURTHER READING

Beery, Pauline G. *Chemistry Applied to the Home and the Community.* J. B. Lippincott Company, Philadelphia, 1926.

Bolduan, Charles F., and Bolduan, N. W. *Public Health and Hygiene.* W. B. Saunders Company, Philadelphia, 1937.

Chenoweth, L. B., and Morrison, W. R. *Community Hygiene.* F. S. Crofts & Co., New York, 1936.

Ehlers, V. M., and Steel, E. W. *Municipal and Rural Sanitation.* McGraw-Hill Book Company, Inc., New York, 1937.

Johnson, Ava L. *Bacteriology of the Home.* The Manual Arts Press, Peoria, Illinois, 1929.

Pigman, Augustus. *A Story of Water.* D. Appleton-Century Company, Inc., New York, 1938.

Steel, Ernest W., and White, E. G. *Hygiene of Community, School, and Home.* Harper & Brothers, New York, 1937.

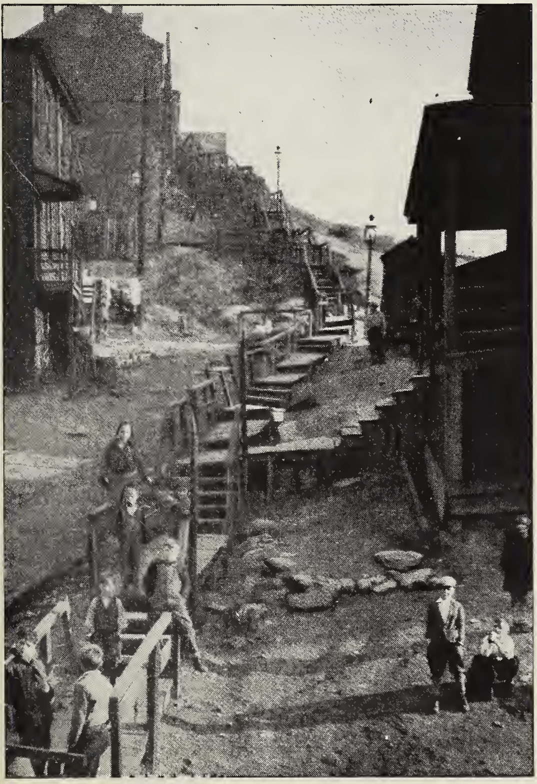
The Chemistry of the Disposal of Sewage and Other Wastes

One of the important processes that must be carried on by any living organism is that of the removal of the waste materials of its body. No matter how small or large the organism may be, if it cannot adequately and completely remove its own waste substances, it will die. The same natural law holds with groups of organisms which are living together as a unit. Man is no exception, and the removal of wastes from modern communities is therefore an important problem to him. In fact, life in our large modern cities would be impossible if the wastes of the populace were not efficiently and effectively removed. Some authorities attribute the decay and fall of cities of past civilizations to the simple fact that people did not know how to dispose efficiently of waste and sewage.

The knowledge of the necessity and of satisfactory methods of removing wastes is of more recent origin than most people believe. You must remember that the idea that disease originates with bacteria and other microorganisms is only about seventy years old, and that before the time of Pasteur and Koch people were not health-conscious. Before that time, people did not associate ill health or the spread of

In the modern apartments at the right, unlike the unsanitary dwellings at the left, the efficient disposal of wastes makes for the health of the community

Ewing Galloway



United States Housing Authority

Ewing Galloway

Vegetables grown in some irrigated sections may be contaminated with sewage. They should always be washed thoroughly before being used

disease with pathogenic bacteria. Nor did even the scientists know that this type of bacteria contaminate sewage. The common method of the disposal of waste from the kitchen was to discharge it into the streets. The streets of medieval cities were revolting places, where garbage and refuse were allowed to accumulate and decay. This method of the disposal of wastes was so common that the levels of the streets rose about one foot each century, and narrow streets had risen several feet during the time that people had lived in them. It was against the law to put excreta or other solid wastes in the sewers in the "enlightened" city of Paris until the year 1880. In England there had been similar laws in every city, but most of them had been repealed by 1860. The application of sanitary knowledge spread very slowly, so that we can safely say that sanitary plumbing and effective waste disposal are only about seventy years old.

Now that more and more people are living in cities, it is becoming increasingly important that everyone be aware of the fact that waste disposal is a community problem; and if modern practices of refuse disposal are followed by families in rural areas and cities alike, people will be rewarded with better health and living conditions.

PURPOSES TO BE ACHIEVED

1. To understand the relationship between health and waste disposal.
2. To become familiar with proper methods of waste disposal.
3. To realize that waste disposal in a city is a community problem.
4. To learn the nature of wastes.

PROBLEMS TO BE SOLVED

1. What are the waste products of a community?
2. What are the dangers which result from the improper disposal of wastes?
3. How does a modern city dispose of its sewage and other refuse?
4. How are refuse and other waste material disposed of in rural communities and homes?

Problem 1. What are the waste products of a community?

Communities have many waste products. All the activities of living are accompanied by the production of refuse. Many products and articles which were once useful are discarded and become waste materials. The final disposition of all these wastes is a major problem of every city and rural community.

While there are hundreds of individual items of waste, most of the refuse of a community or a family may be divided into the following classes:

1. *Rubbish.* Mixed dry material made up of discarded clothing, cans, boxes, bottles, broken dishes, etc.
2. *Garbage.* Waste materials from kitchens and slaughterhouses, usually part liquid and part solid.
3. *Ashes.* The mineral, unburnable substances left from coal and wood fires.
4. *Sewage.* Waste material and excreta from streets, industrial plants, and toilets, and water from laundries and kitchens. Sewage is generally in a semiliquid condition.

EXERCISES

1. How long have we known that diseases were spread by unsanitary disposal of wastes?
2. What important relationship exists between the removal of wastes and life?
3. Why should you study the chemistry of sewage disposal?
4. What are the waste products of a community?

Problem 2. What are the dangers which result from the improper disposal of wastes?

Improper waste disposal spreads disease. The members of a family or the citizens of a community who neglect to dispose of sewage and other wastes properly are responsible for more sickness, more deaths of babies, and higher general death rates than are necessary. Ill health from improper waste disposal is produced in two ways. First, there is much direct contamination of water, milk, and foodstuffs, such as vegetables, which have been grown on land irrigated with contaminated water. Second, mosquitoes, flies, and animals serve as hosts, or carriers, of germs which they obtain from direct contact with exposed garbage and sewage.

You may obtain data from your state department of health showing that there is a definite relationship between the number of deaths from typhoid fever, amoebic dysentery, and infectious diarrhea, on the one hand, and the careless disposal of garbage and the discharge of raw sewage into streams or rivers, on the other. Such information has been collected for many communities, and it shows that where waste is improperly disposed of, sickness from these diseases is much more prevalent, and deaths are more numerous, than in those communities where sanitary practices are followed.

Improper waste disposal is costly. There have been many cases in United States courts where a city upstream from another city has been sued because of stream pollution caused by the dumping of sewage in the river. Damages have been awarded to the offended city and collected by it. The increased cost of water purification in some communities can be traced to the contamination of the water by sewage.

If garbage is left exposed, it encourages the propagation of rats, which are carriers of bubonic plague. Rats in a city are costly to eradicate and add greatly to the general filth. The additional sums spent by the health department to combat the diseases caused by improper waste disposal are not small items in the annual budget.

Improper waste disposal in a farm home may cost a family untold misery, sickness, and even death.

The accumulated garbage in alleys, the rubbish dumps in low places, and shallow sewage-disposal streams offend the sight and smell of people so much that visitors and tourists get a poor impression of a community in which such conditions obtain. If a city wants the trade of tourists, it should dispose of all its wastes properly, because people know that to do otherwise is a menace to health.

Other harmful effects of the pollution of streams by sewage are (1) the killing of the fish in the streams, (2) damage to livestock, and (3) unsanitary recreational facilities.

EXERCISES

1. State specifically how the improper disposal of wastes spreads disease.
2. What diseases have been definitely proved to be traceable to the improper disposal of sewage?
3. Does it cost a city more to dispose of sewage and other wastes properly than not to have any disposal system? Why or why not?

Problem 3. How does a modern city dispose of its sewage and other refuse?

Methods of sewage disposal. Sewage from most cities contains about 99 per cent water and 1 per cent solids, which are made up of floating solids, settleable solids, fats and oils, solid matter which will putrefy, and bacteria and other microorganisms. The main object of the proper disposal of sewage is to remove the solids and enough of the bacteria to make the remaining solution harmless when it is finally discharged into a stream. The liquid which is discharged is known as the effluent.

Discharging untreated, or raw, sewage into streams. One of the older methods of sewage disposal is to discharge untreated sewage into a stream near the edge of a city or town. This is always an unreliable method unless there is a sufficient volume of water in the natural flow of the stream to provide enough oxygen to oxidize the harmful bacteria completely. There must also be a very fast flow to carry all the solids away. There are few streams that have the capacity and the rapidity of flow necessary for this method of treating sewage. Lakes are never satisfactory as a depository, and the ocean is only suitable if the tides are fast. Some people think that if water travels twenty feet in the sunlight, it purifies itself. This is very untrue. Running water which contains sewage may become clear, but clear water is not necessarily pure water.

How does sewage purify itself? If sewage is poured on loose soil or in a sufficient volume of water, it will eventually clarify, and the effluent will be found to contain no harmful bacteria. This natural action is itself due to bacteria which cause decay but do not produce harmful bacteria. There are two different kinds of decay bacteria which act upon excreta and other putrescible matter. They are known as (1) anaerobic bacteria, which do not require oxygen, and (2) aerobic bacteria, which need oxygen to live. The decay produced by anaerobic bacteria has a foul odor and is sometimes called putrefaction. The decomposition brought about by aerobic bacteria is odorless. The work of this type of bacteria is to change organic matter into a stable inorganic form. That is, proteins are converted into nitrates and nitrites which are available to plants as food.

Both kinds of bacteria are generally at work on sewage; the kind which predominates depends on the amount of oxygen which is present. If sewage is spread on soil, it soon becomes odorless because of the action of aerobic bacteria, which always exist in the first few feet of soil.

Modern sewage-disposal plants. Sewage-disposal plants are classified according to the degree of purification which they are able to obtain in the effluent. They are known as preliminary-treatment plants, primary-treatment plants, and secondary-treatment plants.

1. *Preliminary-treatment plants.* These plants merely remove some of the solids by a process of screening and settling.

2. *Primary-treatment plants.* These plants are used where complete treatments are not necessary, because the stream into which the sewage is dumped has sufficient flow of water to dilute the sewage below the danger point. These plants consist of large clarifying tanks into which the raw sewage, after passing over bar filters to remove some solids, is allowed to settle and purify. Anaerobic bacteria are the active purifying agents, since no oxygen is present. These plants remove about 75 per cent of the solids.

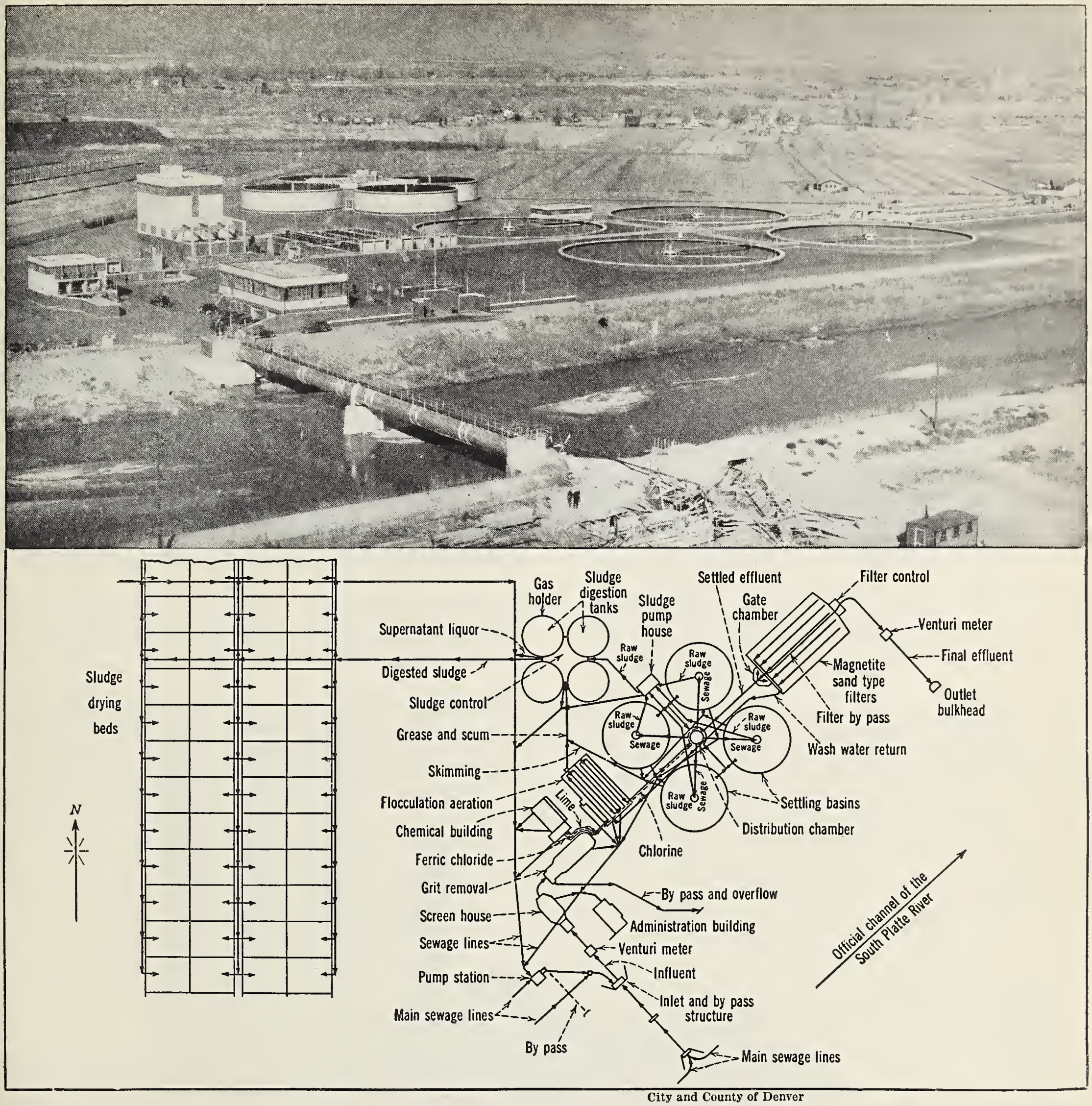
3. *Secondary-treatment plants.* These plants are used in combination with some preliminary-treatment and primary-treatment plants. Such plants can produce a very pure effluent, but generally the goal is about 90 per cent to 95 per cent purification. In this process the sewage is first screened and then settled in large sludge tanks, where it is kept in contact with nitrifying bacteria for from four to six hours. The bacteria are provided with sufficient oxygen by automatic devices which bubble air through the sludge. Then the effluent is decanted off, filtered, and discharged into a stream. The settled sludge is pumped to digesting tanks, where it is kept at a constant temperature of 95° F for several hours and is then pumped to drying beds, where it is dried and is sold as fertilizer, or it may be burned in incinerators.

A variation of the activated-sludge method, just described, is found in the chemical-precipitation plants. In these plants ferric chloride or ferric sulfate and lime are added to the sewage to coagulate, or settle, it. The reaction which takes place is

$$2\,FeCl_3 + 3\,Ca(OH)_2 \longrightarrow 3\,CaCl_2 + 2\,Fe(OH)_3 \downarrow$$

Since the $Fe(OH)_3$ is an insoluble jelly-like precipitate, it carries the solid particles and bacteria out of suspension as it settles to the bottom of the tank. The effluent is then filtered off and is ready to be discharged. From 75 per cent to 80 per cent of the suspended solids are removed in this process. Though this method is more costly, it is also more efficient. No bacterial action takes place in the chemical-precipitation method. It is entirely chemical and is in no way biological. If the effluent is filtered through a fine-grained filter and chlorinated, the process is known as a complete treatment. This is not usually necessary, since the oxygen of the water in the stream into which the effluent is discharged is generally sufficient to complete the natural oxidation of any remaining impurities.

The cost of operating a modern sewage-disposal plant varies from 70 cents to $2 per person a year.



City and County of Denver

In this modern sewage-disposal plant the city of Denver treats all its sewage in a healthful, scientific manner. In the foreground is shown the Platte River, into which is poured the effluent coming from the sewage-disposal plant. This effluent contains no disease-producing bacteria when it is discharged into the river. The solids, which are dried on the drying beds at the right of the picture, make a valuable fertilizer. Such a disposal plant pays for itself many times in terms of lives saved and the general health of the citizens of the community

In the most efficient plants the cost of operation is reduced about one-half through the sale of sludge as fertilizer. These modern plants do not require a large force of men, as most of the controlling apparatus is operated mechanically. The flow of sewage through a plant is continuous, and there is no stoppage of any part of the plant except for occasional cleaning and repairs.

The disposal of garbage. Garbage is a valuable waste material because it may be fed to hogs and thus be converted into money, or it may be reduced to valuable by-products which can be sold at a profit. There are many ways to dispose of garbage.

Converting waste to food. Many cities feed garbage to hogs. Generally a contract is let to some private company which agrees to collect the garbage regularly. Sometimes the collectors are paid by the city for this service, but more often the profit from the feeding of the hogs is more than adequate pay. This is an interesting method of converting a waste product into a valuable food. The meat from hogs fattened on garbage has been tested and found to be just as good as that from hogs fed on grain.

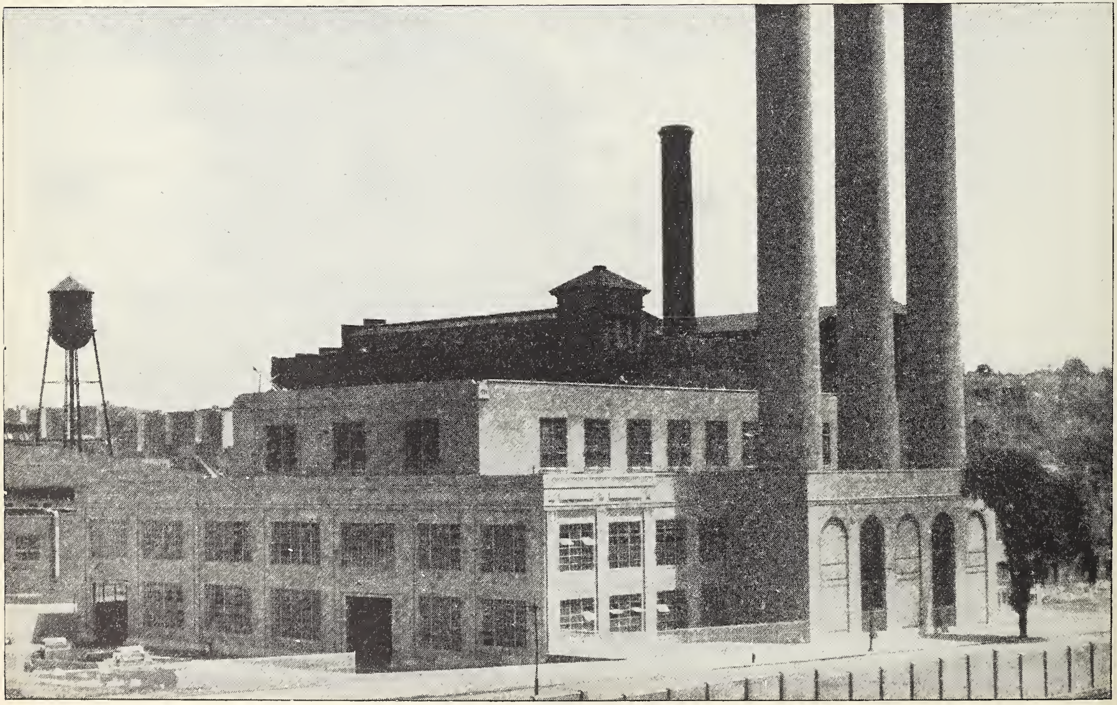
Incineration. Garbage contains burnable materials if it is first dried. Therefore the method of incineration is a way of disposing of garbage used by certain cities. This is a costly method because there are no by-products to be sold at a profit.

Dumping garbage on land or water. It is not uncommon for garbage to be spread on farm land as a fertilizer. Sometimes it is dumped into the ocean, lakes, or rivers. Sometimes it is merely deposited on the outskirts of a city. These methods are all unsatisfactory and unsanitary.

Garbage disposal by reduction. This is a very efficient method of garbage disposal for large cities. Because of the expense of installation of the plant, which necessitates large volumes of garbage for efficient operation, this method is not suitable for a city with a population of less than 125,000. In general, the process is one of removing the oils and greases from the garbage and leaving the solids. It is called reduction because the garbage is broken

Burning garbage in incinerators. This is a costly but sanitary method of garbage disposal

Ewing Galloway



down by steaming and cooking. After being cooked for several hours, the oil is skimmed from the top. The solids are pressed and mixed with some fat solvent, such as benzine or carbon disulfide, to remove the remaining fat and grease. The solvent is filtered off and then distilled, leaving the grease as a residue.

Both the oils and the solids, known as tankage, have value. The oil is sold to soap-manufacturers, and the tankage is sold as a base for fertilizer or is used as a fuel to burn under the boilers of the heating plant.

Disposal of rubbish. Rubbish has some value, since many people throw away useful or valuable articles. Therefore some cities place the collected rubbish on conveyers, from which men pick out the things of value. Often money and jewelry are found; such articles as jewelry can be sold. After articles of value have been salvaged, the rubbish is destroyed because it may harbor disease germs and filth. The best method of disposal is incineration. The ashes can then be used to fill in lowlands.

Disposal of ashes. Ashes are most cheaply disposed of by dumping them in low places to raise the level of the land. In this manner, swampland has been reclaimed by some cities. Ashes generally contain only the mineral constituents of fuels and do not have any bacterial or disease-producing qualities.

EXERCISES

1. What is the principal problem in the disposal of sewage?
2. What are the disadvantages of discharging sewage into streams?
3. How does sewage purify itself?
4. What is the difference between aerobic and anaerobic bacteria?
5. Describe the actions which take place in a modern sewage-disposal plant.
6. What are the best ways to dispose of garbage?
7. Describe the reduction method of garbage disposal.
8. How should rubbish and ashes be disposed of?

Problem 4. How are refuse and other waste material disposed of in rural communities and homes?

Sanitation in rural districts. The proper disposal of waste materials in rural homes and towns is of tremendous importance to the health of the people who live there. Government health agencies report that no other health measure has been so instrumental in producing good results as has their campaign for the adoption of sanitary outhouses in rural districts. The number of cases of typhoid has been reduced, and the general health of the people in rural districts has been improved.

Sanitary rural toilets. Sanitary outhouses can be constructed in the country, even though there is no running water. Your state department of health or the United States Public Health Service will furnish exact information on how to build sanitary toilets. The general principle involved is to make them absolutely flytight and at least one hundred feet away from a well. Open-pit toilets are a serious menace to health. Flies, chickens, and other insects and animals which have easy access to the human excreta of the toilet spread the germs of many diseases. Much hookworm disease is spread by the open-pit toilet. A box of chlorinated lime should be kept in outhouses. If this chemical is occasionally poured into the pit, it will do much to keep the toilet sanitary and free from odors.

Chemical toilets. These toilets have a toilet seat which is similar to those used in the modern bathroom. A tank is located beneath the seat, in which is placed a lye solution. This chemical tends to liquefy the solids and kills the germs. The liquid refuse may be conducted away and allowed to seep into the soil. Chemical toilets are nearly odorless and are very efficient in operation. They are more costly than pit toilets, but their sanitary features make them highly desirable where water is not available. They are recommended for rural schools which do not have running water.

Water toilets for rural homes. Many homes in rural communities and towns have running water, but since there are no sewers, other methods of sewage disposal have to be used. One method is that of running the sewage into cesspools or septic tanks.

A *cesspool* is simply a well into which the sewage is discharged. It is constructed of loose rock so that seepage into the surrounding soil will take place gradually. Its disadvantages are that the gradual accumulation of the solids causes clogging of the outlets, and the effluent overflows. This is unsanitary and produces foul odors. Moreover, if cesspools are built in limestone rock, the effluent has been known to flow through cracks and crevices for distances of a mile or more into drinking-water sources. Therefore cesspools should be used only where the surface soil and the subsoil are loose sandy loam. A new cesspool must be dug every five to ten years.

Septic tanks are more efficient and more sanitary than cesspools. They are similar to cesspools except that they do not allow for seepage. They are built of concrete, brick, or metal. The sewage is retained in the tank for at least twenty-four hours. Anaerobic bacteria act upon the sewage, and the solid matter gradually settles to the bottom. The bacterial action causes much of the solid content of the sewage to be converted into liquids and gases. The liquid effluent is drained off regularly into loose sandy soil. The effluent may contain harmful, or pathogenic, bacteria, and it should not be discharged on the surface of the ground or near the source of a water supply. The solid matter which settles in the bottom of the tank must be removed every few years so that the tank will continue to operate efficiently. The septic tank is by far the best means of disposing of sewage where sewers are not available.

EXERCISES

1. What results have been accomplished by the proper disposal of wastes in rural communities?

2. What common chemical substance may be used to keep open-pit toilets more sanitary?

3. What diseases are spread by open-pit toilets?

4. Describe the installation and operation of water toilets for rural homes.

5. What precautions should be observed in the installation of septic tanks?

PROBLEMS FOR FURTHER STUDY

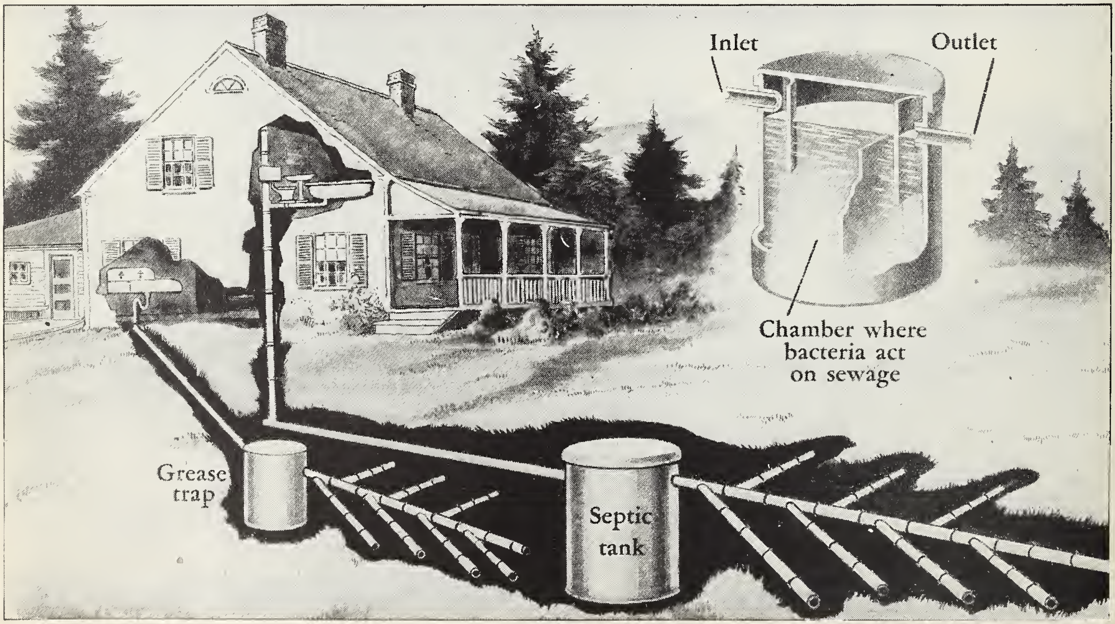
1. How is the sewage of your community treated?

2. How is garbage disposed of in your home or community?

3. What is the value of the fertilizer sold from a modern sewage-disposal plant?

4. Make a study of the diseases which may be transmitted by improper sewage disposal to determine

a. Whether, in communities where modern sewage plants have replaced antiquated methods, there is any



A sewage-disposal system for a single residence. The septic tank serves as a reservoir for the sewage[1]

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[1] Reproduced from Caldwell and Curtis's *Science for Today*, Ginn and Company.

difference in the number of people who die from these diseases.

b. What the annual death rate for these diseases is in the whole nation and how it compares with the annual death rate in your community.

UNIT EXERCISES

The statements which follow are incomplete. On a separate sheet of paper write whatever is necessary to complete each statement correctly. Do not write in this book.

1. To live healthfully every living organism must remove its --(?)--.

2. People have been aware of the necessity of removing sewage and other wastes in an effective manner for about --(?)-- years.

3. We should study the chemistry of sewage disposal to understand the relationship between --(?)-- and waste disposal.

4. The types of waste materials found in most cities are --(?)--, --(?)--, --(?)--, and --(?)--.

5. The improper disposal of wastes is likely to bring about direct --(?)-- of such things as garden vegetables, --(?)--, and --(?)--.

6. The improper disposal of wastes also brings about indirect contamination by allowing insects such as --(?)-- and --(?)-- to come in direct contact with exposed sewage and garbage.

7. The proper disposal of sewage and other wastes costs --(?)-- than improper disposal.

8. If raw sewage is discharged into streams, three of the harmful effects produced are --(?)--, --(?)--, and --(?)--.

9. The main problem in the disposal of sewage is to remove the --(?)-- and kill enough of the --(?)-- so that the remaining solution is harmless.

10. The two kinds of bacteria which act upon sewage are known as --(?)-- and --(?)--.

11. --(?)-- bacteria require oxygen.

12. --(?)-- bacteria do not require oxygen.

13. The decay produced by the type of bacteria which require no oxygen is sometimes called --(?)--.

14. For sewage to be completely purified, it must be subjected to what is called the --(?)-- treatment.

15. $2\,FeCl_3 + 3\,Ca(OH)_2 \longrightarrow 3\,CaCl_2 +$ --(?)--.

16. The cost of operating a modern sewage-disposal plant runs from --(?)-- to --(?)-- per person a year.

17. The liquid which is discharged from a sewage-disposal plant is known as the --(?)--.

18. The dried sludge from sewage-disposal plants may be sold as --(?)--.

19. Garbage may be disposed of by --(?)--, --(?)--, or --(?)--.

20. The best method of destroying rubbish is to --(?)-- it.

21. --(?)-- disease is often spread by the open-pit toilet.

22. A box of --(?)-- should be placed in the outdoor toilet.

23. Chemical toilets contain the substance commonly known as --(?)--.

24. A septic tank differs from a --(?)-- in that it does not allow --(?)--.

25. Septic tanks are the best means of rural sewage --(?)-- where --(?)-- is not available.

REFERENCES FOR FURTHER READING

Bolduan, Charles Frederick, and Bolduan, Nils William. *Public Health and Hygiene.* W. B. Saunders Company, Philadelphia, 1937.

Ehlers, Victor M., and Steel, Ernest W. *Municipal and Rural Sanitation.* McGraw-Hill Book Company, Inc., New York, 1937.

Hering, R., and Greeley, S. A. *Collection and Disposal of Municipal Refuse.* McGraw-Hill Book Company, Inc., New York, 1921.

Metcalf, L., and Eddy, H. P. *Sewage and Sewage Disposal.* McGraw-Hill Book Company, Inc., New York, 1930.

Steel, E. W., and White, Ella G. *Hygiene of Community, School, and Home.* Harper & Brothers, New York, 1937.

UNIT 31

The Chemistry of Food Production and Distribution

When the housewife in an apartment in New York City goes into her kitchenette and surveys the foods on the shelves or in the refrigerator, she may give little thought to the vast mechanism in our industrial world that has made possible such a wide variety of foods. She may have on hand fruits from California, Texas, or Cuba; vegetables from Michigan or Florida; butter or cheese from Wisconsin; beef from Colorado; pork from Iowa; potatoes from Idaho; eggs from Nebraska; and milk from upstate New York.

In order that the housewife may have fresh but perishable foods, special transportation facilities, including fast trains and modern refrigerator cars, speed the foods to market. Through years of experience and research, modern methods of handling, crating, buying, and distributing have been developed.

When the housewife goes to the grocery store, she has difficulty in selecting the best "buy" when she sees the vast array of foods available, the variations in price of commodities, the perplexing variety of sizes of cans and packages, the number of different brands of the same item, and the number of grades available. How is she to know whether the meats on display were obtained from healthy animals and handled in a sanitary manner? How can she be sure that the canned goods she buys contain no harmful preservatives or adulterants? How can she be sure that the food she buys in restaurants was prepared from wholesome materials and served in a sanitary manner? What are the safeguards that have been established which guarantee that the milk, butter,

What measures are used in the modern food market to prevent food from becoming contaminated and to protect the health of consumers?[1]

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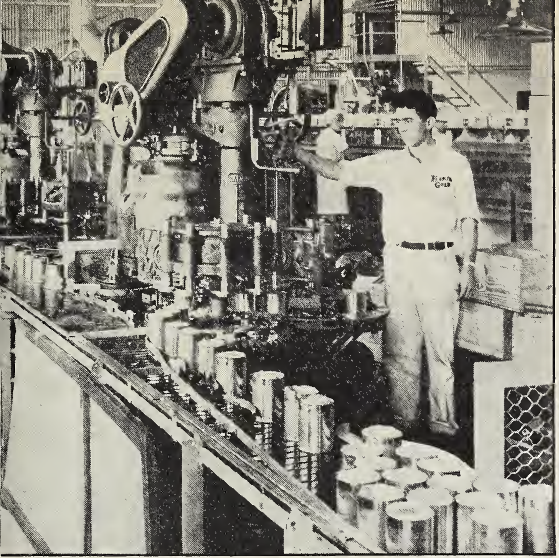
[1] Reproduced from Twiss's *When I Go to Work*, Ginn and Company.



American Can Company

Cans filled with grapefruit being sealed by machinery in a Florida cannery

ice cream, and other dairy products that she purchases for her family are pure and wholesome?

Many agencies have been set up by the Federal, state, and municipal governments that do much to safeguard the consumer. However, much remains to be done. The standardization and grade classifications of commodities have yet to be accepted and enforced on a large scale. The consumer must be made conscious of the various aids which are being established and learn how to use them wisely. The extent to which these protective measures can be made effective depends on the demand for them of the consumers themselves.

At present, the housewife must depend largely on her own judgment and experience in selecting the food for the family. If she is careful, observant, and uses all the aids which are available, she will be more certain of securing wholesome foods at reasonable prices.

PURPOSES TO BE ACHIEVED

1. To learn what protection is afforded the consumer in purchasing food.
2. To learn how foods are graded and labeled.
3. To learn how modern packaging has made the distribution of foods more sanitary.
4. To become acquainted with some of the unsanitary practices used in the distribution of foods.

PROBLEMS TO BE SOLVED

1. How is sanitation practiced in the distribution of foods?
2. How do government agencies protect the consumer?
3. How can the consumer determine the quality of the food to be purchased?

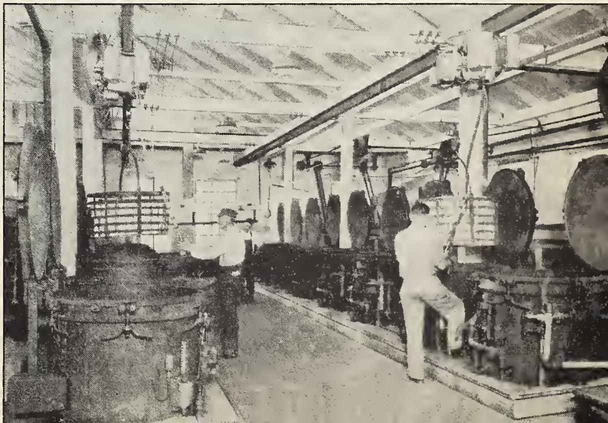
Problem 1. How is sanitation practiced in the distribution of foods?

Modern packing. Many commodities are now available in sanitary packages. The production of many commonly used foods has become so mechanized that the handling of them and chances of contamination have been greatly reduced.

Bread is manufactured in bakeries from raw materials, wrapped in oil paper, and sealed without the touch of the human hand. Fresh vegetables cut for salads are packed and sealed in "Cellophane" bags. This ensures crispness by preventing the evaporation of water and ensures purity by preventing contamination by flies, dust, and other carriers of germs. Many goods formerly sold in bulk are now sold in "Cellophane" bags. The advantages of this method of packaging are (1) the goods are protected from contamination by bacteria which may be in the air or on the hands of people handling them; (2) the customer sees what he buys; (3) the goods are protected from oxidation, so that vitamin content is preserved, and deterioration and rancidity are retarded; (4) the flavor is preserved by preventing loss of essential oils through evaporation.

Sealed cans of food are usually heat-processed for a certain length of time at a high temperature in large vertical retorts

American Can Company



E. I. Du Pont de Nemours & Co.

This cake is protected from dirt and bacteria because it is sealed in "Cellophane" (cellulose film)

In addition to "Cellophane" packaging, many foods are wrapped or sealed in paper, placed in heavy paper or cardboard cartons, and then wrapped or sealed in decorative material or material on which a description of the contents is printed.

A good practice for consumers to follow is, when they have a choice, to buy only those goods which are sold in sanitary packages. It is now possible to buy all cuts of meats and fish, poultry, and even vegetables wrapped in neat sanitary packages. Though the practice of selling many foods, such as steaks and chops, already cut and packaged in "Cellophane" is not common, the present-day meat market, with its meat blocks, open meat-grinding machines, and exposed meats, may in time become as obsolete as the open cracker barrel in the grocery store.

Refrigerating. Modern refrigeration cars speed toward the large cities, carrying fresh fruits, vegetables, and meats from the producer to the consumer. Wholesale houses quickly transfer the goods from the train to cold-storage vaults. Soon the food is in the retail store ready for sale to the housewife. Many stores now have attractive refrigerated display cases, in which are placed the fruits, vegetables, and meats. The modern storekeeper knows that housewives are becoming more sanitation-conscious.

Meat adulteration. Unscrupulous retailers may use spoiled meats in making ground meat. Preservatives, such as formaldehyde ($HCHO$) and benzoate of soda, may be added to ground meats to prevent further spoilage. Sodium nitrite ($NaNO_2$) may be added to aged meat to restore its fresh red color. Meal or flour may be added to ground meats to increase their bulk and weight. All these practices are unhealthful and in most states unlawful. Many housewives insist upon having their meat ground when purchased to be sure that they are getting a choice wholesome product. Packaged meats are protected against exposure to bacteria and dirt. The consumer should observe the sanitary condition of meat markets and refuse to buy meats from any but those places which are scrupulously clean and neat.

EXERCISES

1. What general safeguards are afforded the consumer in purchasing food?
2. How has modern packaging improved the distribution of food?
3. Explain the sentence "Housewives are becoming more sanitation-conscious."
4. How do some unscrupulous meat dealers treat partially decomposed meat to make it appear fresh?

The best sanitary conditions cannot be maintained in an open market such as that shown here

Consumers Union

Problem 2. How do government agencies protect the consumer?

The Federal government aids in food protection. The production and distribution of food have become a tremendously large industry in this country within the last fifty years. No longer does the community produce most of the food it consumes. Food is shipped from one part of the country to another, and the consumer has no means of knowing under what conditions it was produced or how it was handled in shipping unless some agency sets up certain standards and sees that they are enforced. The health of the people of this country depends upon the enactment of such measures by law. Where goods are produced in one part of the country and shipped to another, the problem becomes national in scope and can only be attacked by the Federal government. The Federal Food, Drug, and Cosmetic Act became a law on June 25, 1938. Most of its provisions became effective one year from that date. The parts of the law which are of particular interest to the consumer from the point of view of the protection they afford him in the purchase of foods are as follows:

1. It prohibits the sale of foods which may be injurious to health.
2. It forbids traffic in confectionery containing metallic trinkets and other inedible substances.
3. Labels must state the presence of artificial coloring, artificial flavoring, and chemical preservatives in foods; but butter, cheese, and ice cream are exempt from the artificial-coloring provision.
4. Special dietary foods must contain labels informing purchasers fully of vitamin, mineral, and other dietary properties.
5. It sets up definitions for different types of food, standards for the identity of food, reasonable standards of quality, and standards for the fill of containers. Exemptions are made for some fresh and dried foods and vegetables.
6. It prohibits the use of uncertified coal-tar colors in foods.
7. It outlaws the slack filling of food-containers and prohibits the use of deceptive containers.
8. It authorizes the inspection of establishments producing food for interstate shipment.
9. It prohibits the use, either in part or in whole, of a decomposed, dirty, or spoiled animal or vegetable substance or any portion of an animal unfit for food. It also prohibits the use of a diseased animal or one which has died otherwise than by slaughter.
10. It prohibits the use of certain methods for concealing damage or inferiority, such as staining, coating, powdering, or coloring.
11. It defines what constitutes adulteration in foods, including the substitution and addition of other substances to reduce strength or quality or to increase bulk.
12. It prohibits the sale of one food under the distinctive name of another. Oleomargarine cannot be sold as butter.
13. It requires that the labels of all packaged goods contain a correct statement of weight or measure or of the numerical count of the contents.
14. It prohibits the printing of misleading or false statements on the labels of foods.
15. It requires the printing of the grade or quality on the labels of some foods.

The law is made effective by the establishment of food-testing laboratories and the organization of inspection bureaus. Federal food-inspectors examine the food in process of production, and secure samples in warehouses, in transit, at wholesalers', and from retail stores. They are well trained; and since they are in the employ of the United States government, they are not subject to the control of producers.

State health departments. Since the Federal pure-food laws apply only to goods produced for interstate shipment, they offer little protection to the consumer where goods are produced, sold, and used within the boundaries of a state. Every state has set up health departments and food-inspection bureaus for the protection of its citizens. Some of these are more elaborate and efficient than others. State agencies are more likely to be under political control than the Federal agencies and consequently are usually less efficient and effective. In most states pure-food laws and their enforcement are inadequate. There are some states, however, which give more protection to the consumers than the Federal government.

City health departments. One of the functions of a city government is to protect the health of its citizens. To do this, it must, among other things, see that all foods sold in the city are pure, protected from bacteria, kept in sanitary places, and handled by healthy people. Many cities prohibit the sale of unpasteurized milk except under special conditions. They also provide for the testing of dairy herds, set minimum limits for the butterfat content and the water content of milk, and establish methods of bottling, cooling, and handling milk.

Meat markets, grocery stores, restaurants, and other places handling foods must meet certain sanitary requirements set up by the city health departments. All these places may be inspected regularly. Persons handling foods may be required to pass periodic health examinations. Soda fountains may be inspected to see that glassware is sterilized after use and that all foods are handled in a sanitary manner.

Consumer judgment. All these agencies have been established to help to safeguard the health of the consumer. In spite of these protective agencies, the consumer must continually exercise his own judgment in the purchase of foods. His experience and observation must still play a large part in his own protection. The enforcement of protective laws is often ineffectually carried out, and constant vigilance on the part of consumers is necessary.

EXERCISES

1. How does the Federal government protect the consumer in food distribution?

2. Which of the provisions of the Federal Food, Drug, and Cosmetic Act of 1938 do you consider the most important from the point of view of health protection?

3. How do state and city health departments compare with the Federal agencies for consumer protection?

4. Over what foods and commodities do cities have special supervision?

Problem 3. How can the consumer determine the quality of the food to be purchased?

Canned fruits and vegetables. Canned foods supply a large part of the diet. They are wholesome and usually free from harmful bacteria. The process of cooking and canning has destroyed little of the food value which would be obtained from cooking fresh fruits and vegetables in the home. They are easy to buy, store, and prepare for use.

Since the contents of a can are hidden from the eye, the consumer must largely depend upon the information printed on the label of the can in determining the quality of the contents. Price is not a sufficient guide, since sometimes a cheaper article is of better quality than one more highly priced. Through experience the housewife should determine the best quality for the price that she wishes to pay.

The only compulsory grade labeling provided for by the Food, Drug, and Cosmetic Act is that substandard fruits and vegetables must be so marked. The law sets up minimum standards for fruits and vegetables and requires that those falling below these standards be marked "Below U.S. Standard." Under this mark may be printed "Good Food—Not High Quality," "Slack Fill," "Contains Excess Added Liquid," or "Low Quality but Not Illegal." For certain cooking purposes, these foods are suitable. Only when they are to be served by themselves does their inferior quality become very apparent. People who must economize will find these foods wholesome and economical.

The following grades of canned fruits and vegetables are defined by the United States Department of Agriculture:

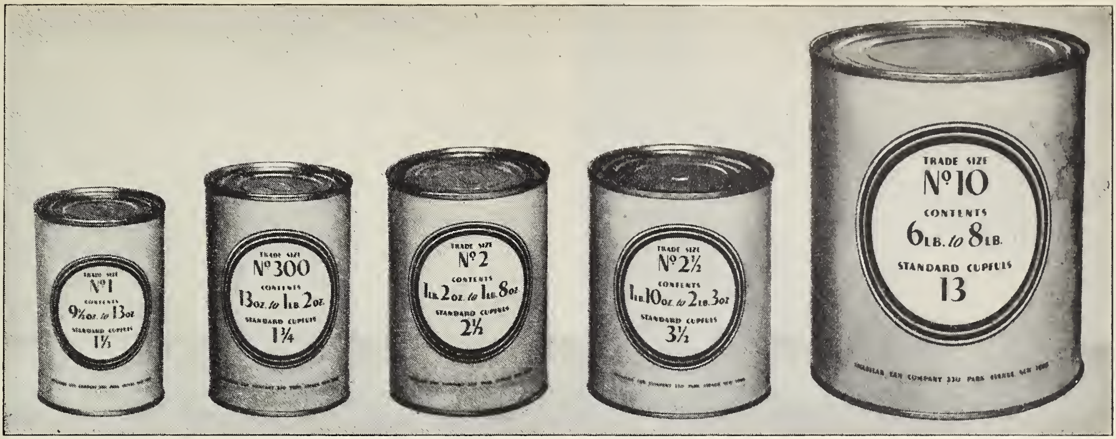
U.S. Grade A, or Fancy
U.S. Grade B, or Extra Standard, Choice
U.S. Grade C, or Standard
U.S. Off Grade, or Substandard

With the exception of the Substandard grade, the use of these grades is not compulsory. Most canned foods are of Grade C quality.

Grade A. Only the finest fruits and vegetables may be labeled "Grade A." Only a small percentage of canned foods meet the requirements of this grade. The products are judged by color, size, flavor, and maturity. The goods in the can are uniform in size.

Grade B. Many people see little difference between this grade and Grade A. The products are selected according to color, size, and maturity but do not have to meet as high a standard as that of Grade A.

Grade C. Most canned fruits and vegetables fall in this class. The products are not as carefully selected as those of Grades A and B, but they are good nutritious food and are cheaper than those of the higher grades.



American Can Company

The intelligent buyer knows the weight content and the volume content of the many different can sizes

Substandard grade. The fruits and vegetables of this grade are wholesome, but they may have some blemishes, may be of poor color, may be irregular in size or shape, and may have been packed when a little underripe or overripe.

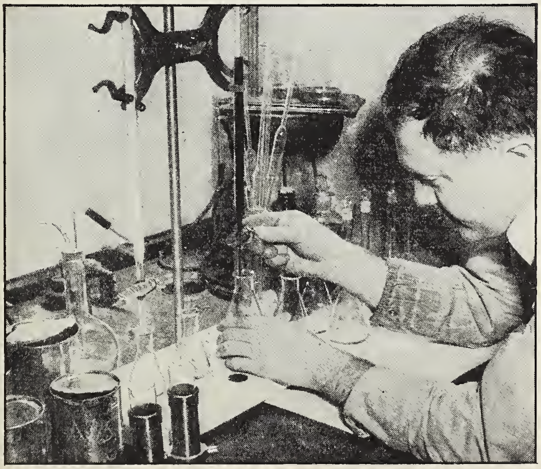
Sizes of cans. There are many different sizes of cans in which foods are sold. It is often hard to determine the size by inspection. The size of the can is not often shown on the label. In comparing various brands, the net weight is the important factor to be considered.

The most common can sizes are as follows:

Size of Can	Volume in Cups	Approximate Weight of Contents
8 ounce (buffet)	1	½ pound
No. 1 tall	2	1 pound
No. 1	1⅓	11 ounces
No. 2	2½	20 ounces
No. 2½	3½	28 ounces
No. 3	4	33 ounces
No. 5	7	3 pounds 8 ounces
No. 10	13	6 pounds 10 ounces

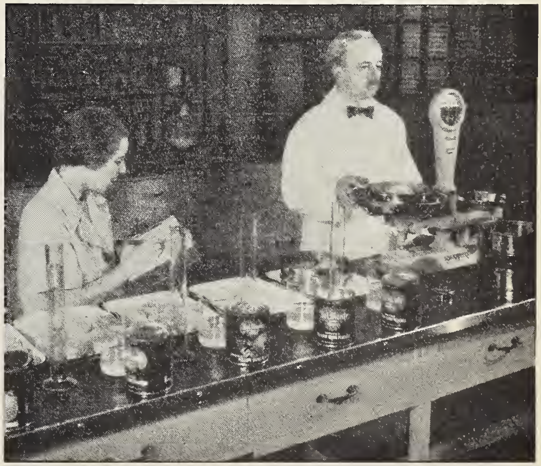
The analysis of fruit juices for their vitamin-C content shows that some brands are consistently superior in this respect to others

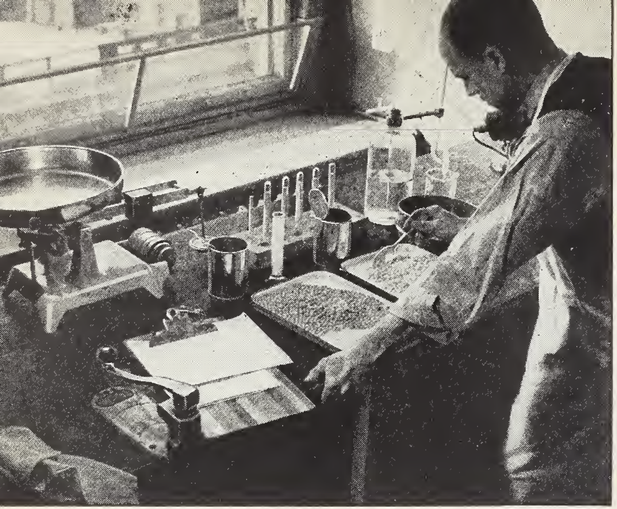
Consumers Union



The selection of canned goods should be based on testing and grading. Your own kitchen provides an excellent laboratory

Good Housekeeping Institute





Consumers Union

This government grader is testing and grading canned foods. Can this be done in your home?

The grading of fresh fruits and vegetables. Many fruit and vegetable growers use the grading system developed by the United States Department of Agriculture, though this is not required. The marking is usually made on the outside of the shipping container, so that it is of little value to the consumer who purchases small quantities on display in stores.

The grades established for most fresh fruits and vegetables are as follows:

First grade—U.S. Fancy
Second grade—U.S. No. 1, or Commercial
Third grade—U.S. No. 2

Only a small amount of fresh products is classed as U.S. Fancy because of the high standards set for variety, color, size, shape, maturity, and freedom from all blemishes. Most of the fruits and vegetables for sale by stores are of second-grade and third-grade quality. Second-grade products are relatively uniform in color, size, and symmetry and are practically free from blemishes. Third-grade products are irregular in size, are not so nearly perfect in color, and may not be so mature. However, for most purposes, particularly for cooking, these products are satisfactory. Care should be exercised in selecting products in the third grade, as the presence of too many blemishes or too great irregularity may result in too great waste. Often a better grade may be the best "buy."

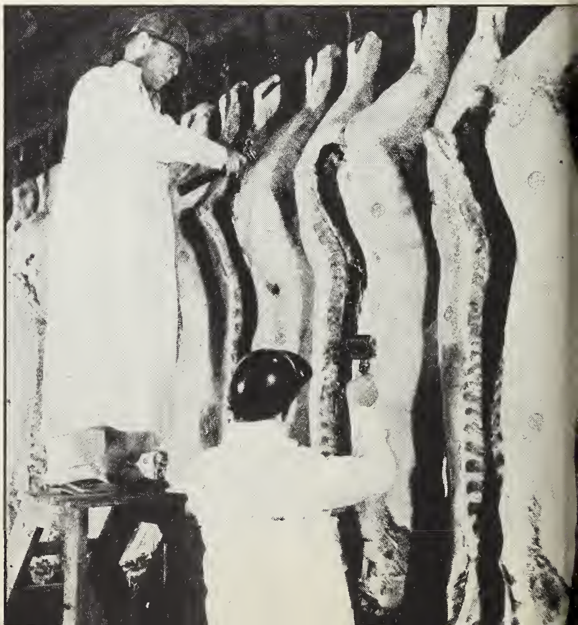
The grading of meats. The grading of meats is required by the government only when the products are to be shipped from one state to another. Government meat-inspectors inspect the vital organs of every animal which is to be processed in packing houses that do an interstate business. Since 1907 the Federal government has allowed only those meat products which come from healthy animals and are sound, wholesome, and fit for human food to be packed and shipped in interstate commerce. Animals which are diseased and unhealthy are condemned and must be converted into fertilizer and like products or destroyed. About 0.3 per cent of the animals butchered are condemned.

The government supervises the methods used in processing to see that they are sanitary and that no harmful ingredients or preservatives are added.

If the meat is approved, it is stamped with the official round purple stamp, "U.S. Inspected and Passed." The ink is a vegetable dye and is harmless. The meat on which the ink appears does not have to be cut off, as the ink usually disappears in the cooking. About 65 per cent of the meat sold in the United States has been inspected and approved by the Federal government. A large amount of meat is butchered and sold within state boundaries, and the consumer has little protection unless

All meat which is shipped in interstate commerce must be inspected and stamped by government inspectors

Ewing Galloway



his own state provides for rigid methods of inspection. Unfortunately this seldom is the case. Consumers are urged to buy only those meats which have been inspected and passed by the Federal government.

What are the grades of meat? The United States Department of Agriculture has set up standards for the grading of meat and has recommended that meat-packers grade-mark all products for retail trade. The grade names are as follows:

	First Grade	Second Grade	Third Grade	Fourth Grade	Fifth Grade
Beef	Prime	Choice	Good	Medium	Common
Veal	Prime	Choice	Good	Medium	Common
Lamb	Prime	Choice	Good	Medium	Common
Mutton	Prime	Choice	Good	Medium	Common
Pork	1	2	3	4	5

The classes of beef in order of quality are steer, heifer, cow, stag, and bull. There is no prime cow beef on the market, and very little stag and bull. Most of the fourth and fifth grades of meat products are sold as canned-meat products.

In addition to the inspection stamp, the government uses a grade stamp of purple ink. This grade stamp may state, for example, "Steer U.S. Choice."

Prime beef is the best. It is well-seasoned and firm. *Choice beef* is almost as good as prime; the difference cannot usually be noticed by the consumer. *Good beef* is wholesome and, though not so fat and tender as choice beef, is desirable food. Most of the beef on the market is *Medium Grade.* This meat is neither well seasoned nor fat, and is likely to be coarse and stringy. If properly cooked, this meat is wholesome and nutritious.

A desirable cut of beef will show these characteristics: the flesh is light red in color when first cut; it is smooth, or velvety, across a fine grain; fine tissues of fat should be interwoven throughout the lean meat, producing what is called a marbled effect. The younger the beef, the lighter the color. The fat should be firm and creamy white in color.

Veal is produced from animals not over twelve weeks of age, and calf meat comes from animals of from three to ten months of age. Ordinary veal is light pink in color, with no marbled effect. Veal of high quality is reddish brown or light tan in color and is fine and velvety in appearance.

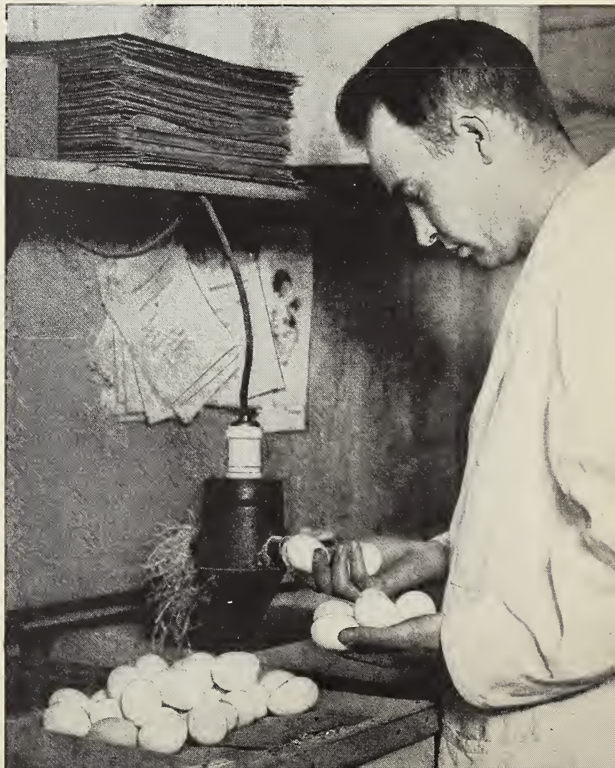
Lamb comes from sheep not over one year or fourteen months old; mutton, from mature animals. The meat from lamb is pink, whereas mutton is dark red in color.

The quality of pork varies less than that of other meats. The characteristics of a desirable cut of pork are firmness, a noticeable marbled effect, and fine grain. The fat should be firm and white. All pork products should be well cooked, as there may be present a parasite which causes the disease trichinosis.

How are poultry products graded? At present, only a small percentage of the poultry sold on the market is graded and stamped by government inspectors. Most of the protection afforded the consumer must come from city health departments, and this is usually very little. The United States Department of Agriculture provides for the marking of only two grades of poultry, "U.S. Prime" and "U.S. Choice." The grade name is printed on a tag which is fastened to the breast or wing of the fowl. These tags are so devised that, when once removed from a bird, they cannot be used again.

Candling eggs with a strong light in a warehouse

Ewing Galloway



Quick-frozen poultry is now on the market in some sections of the country. Each bird is dressed, drawn, and sealed in a "Cellophane" bag. Chicken is stamped as "Stewing," "Frying," or "Roasting." Milk-fed chickens are usually more firm, fat, and seasoned. Quick-frozen poultry has the same texture as that of fresh-killed birds. The sudden chilling to a temperature of from $-20°$ F to $-50°$ F causes the moisture to freeze in small fine-grained crystals, thereby preventing the rupture of tissue fibers which occurs in ordinary freezing, where large crystals are formed.

Eggs in our diet. Eggs occupy an important place in the diet of the American people. The white of an egg is largely albumen and water and contains vitamin G. The yolk has a great variety of food nutrients. It contains the vitamins A, B, and D and is rich in the minerals iron, copper, phosphorus, and calcium. Hens which are exposed to a great deal of sunshine or which are fed cod-liver oil produce eggs rich in vitamin D. Eggs are easily digestible, can be cooked in a variety of ways, and may be used in the preparation of many foods.

How are eggs marketed and classed? The United States Department of Agriculture provides the classification outlined below, which may be used in grading eggs. It is not compulsory. Many states and some cities have similar grading systems and require that eggs for marketing be labeled according to grade specifications.

The grades recommended by the United States Department of Agriculture are as follows:

Grade AA—U.S. Special
Grade A—U.S. Extra
Grade B—U.S. Standard
No Grade—U.S. Trade

Eggs are also graded as to size, such as small, or pullet, medium, and large. Unfertilized eggs will keep longer. Grading is accomplished by a process called candling. This is done by holding an egg up to a light and judging the condition of the yolk and white as seen through the shell.

The freshness and other qualities of eggs depend much upon handling and storage. Eggs left in a warm room for three days will lose more flavor and freshness than eggs stored in a refrigerator for eight or ten weeks.

The preserving of eggs. Since most eggs are produced in spring and early summer, the surplus must be stored for use during the fall and winter months, when the production of eggs is low. The modern cold-storage plant for eggs provides for a scientifically determined temperature and humidity control. Fresh eggs contain carbon dioxide in the air pocket when first laid. As an egg becomes older, the CO_2 diffuses out through the pores, and air enters. The entrance of the oxygen of the air hastens decomposition through increased oxidation. Some cold-storage firms fill the egg-storage rooms with carbon dioxide gas to prevent the loss of CO_2 from the eggs. Eggs are sometimes given a coating of a harmless oil to prevent the entrance of bacteria or odors.

Eggs preserved in cold storage are excellent food and, if kept under scientifically controlled conditions, may be as fresh after months of storage as eggs bought during the summer, which are supposed to be fresh but sometimes are not.

Some farmers and even city residents preserve eggs by packing them in a solution of water glass (Na_2SiO_3). The water glass fills the pores of the fresh eggs and prevents the entrance of harmful bacteria and air.

Frozen eggs are put up by some establishments for the use of bakeries and ice-cream manufacturers. The eggs are removed from the shell, placed in large tin containers, and frozen. Sometimes the whites and the yolks are frozen separately. Candy-manufacturers may buy only the frozen whites, whereas salad-dressing manufacturers may buy only the frozen yolks.

Dried eggs have previously been imported from China. Some drying of eggs is now being carried on in the United States. They are used largely by ice-cream manufacturers, baking-powder companies, and bakeries.

Milk in our diet. Milk is one of the most valuable articles in our diet. It contains such well-balanced amounts of food nutrients that everyone should drink some milk every day. The diet of growing children should always consist of plenty of good milk. While milk is good for both young and old, children need more than adults. In addition to its use as a beverage, milk is used extensively in the preparation of many foods.

Ewing Galloway

Many cities protect their citizens by regulating the quality of milk sold within their boundaries. Officers of the department of health collect samples of milk sold in the city each day for analysis. The woman in this laboratory is testing samples of milk for fat content. Samples from each bottle on the table to the left in the picture will be placed in the flat Petri dishes preparatory to determining the bacterial count

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The average composition of milk is as follows:

Water	87 per cent
Protein	3.3 per cent
Fat	4 per cent
Milk sugar	5 per cent
Mineral salt	0.7 per cent

The two important proteins present in milk are casein, a phosphoprotein, and lactalbumin, an albumin. About 83 per cent of the protein is casein. The curd which forms when milk sours is principally casein. From it are made many different cheeses.

The fat of milk is principally the esters butyrin, caproin, stearin, palmitin, and olein. Butter and whipping cream are products of this fat. It is separated from milk by a cream separator or by allowing the milk to cool and skimming the cream which rises to the top because of its lesser density. The percentage of fat in whole milk will vary with the breed of the cow and with the feed given the cow. Some cows produce milk having 6.5 per cent butterfat, whereas others produce milk having but 2 per cent butterfat.

How is milk graded? The Federal government exercises no control over the grading of milk. However, the code which has been approved and adopted by most large towns was devised by the Bureau of Dairy Industry of the United States Public Health Service. The grading of milk is not strictly enforced throughout the country, and there is some variation in the use of the terms applied to the various grades of milk.

Grade A Pasteurized is raw milk which has been pasteurized, cooled, and bottled in a plant which conforms to specified sanitary regulations. The cows must be tuberculin-tested, the employees must be examined by medical authorities, and the equipment and surroundings must be kept clean and sanitary. An analysis of the milk must not show a bacterial count of more than 30,000 per cubic centimeter.

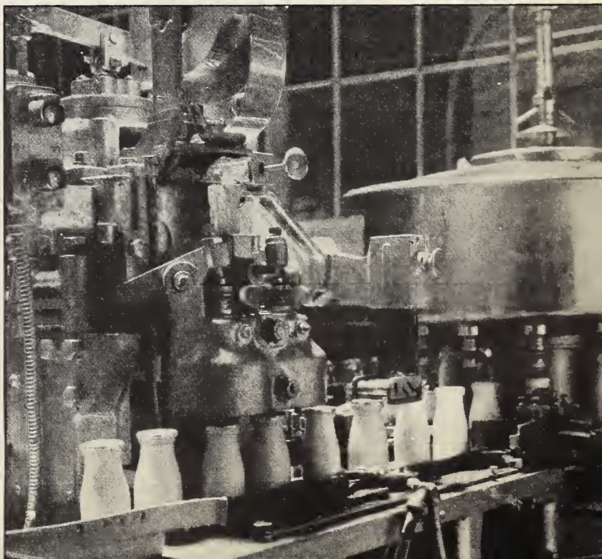
Grade A Raw milk is not pasteurized but must be handled and bottled in the same sanitary manner as Grade A Pasteurized. The bacterial count must not exceed 50,000 per cubic centimeter.

Grade B Pasteurized milk must be produced under the same conditions as Grade A Pasteurized milk except that the bacterial count must not exceed 50,000 per cubic centimeter.

Grade B Raw milk must be produced under conditions similar to those of Grade A Raw milk, but the bacterial count must not exceed 200,000 per cubic centimeter.

A modern milk-bottling machine. The milk does not come in contact with a human hand

Meadow Gold Creamery, Denver

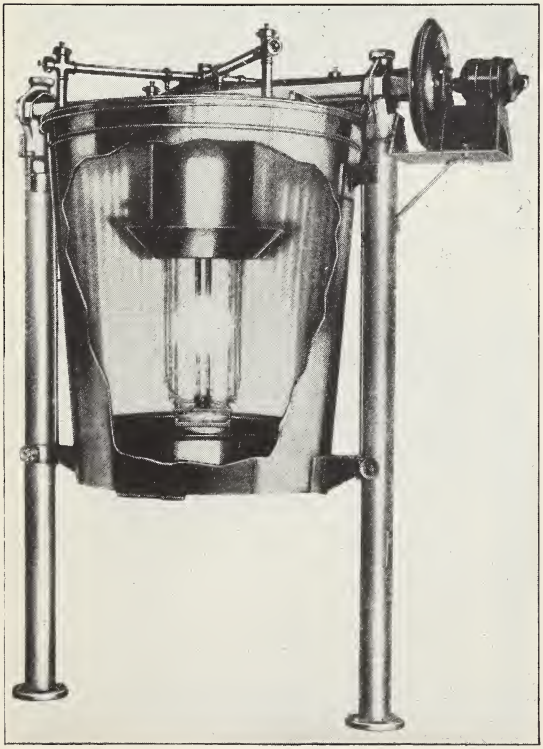


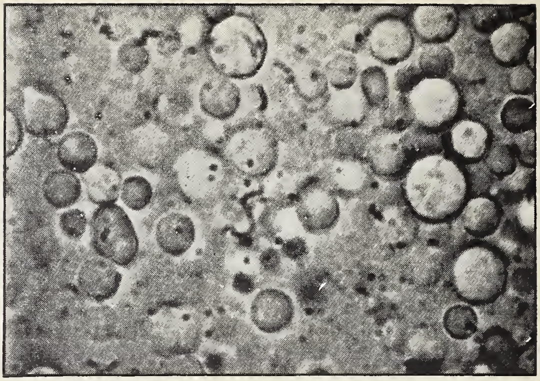
Grade C Pasteurized milk has been pasteurized but will not meet the requirements of Grade B Pasteurized milk. It is labeled "Cooking only" and should be used soon after being purchased, as it will not remain fresh very long.

Vitamin-D milk. Many foods have been fortified with vitamin D. Vitamin-D, or irradiated, milk is made by feeding the cows irradiated yeast or by subjecting the milk to ultraviolet rays or by the direct addition of the vitamin to the milk. It is especially valuable as a food for children during the winter months, when they get little sunshine. Before buying this milk, make sure that the process has been approved by the American Medical Association. Dairies which use methods approved by this association will display their certificates of approval.

In the "irradiator" a thin film of milk flows down the inside of a large, slightly tapering cylinder. Suspended in the center is a special carbon arc lamp, from which come ultraviolet rays. These "sunshine" rays greatly increase the vitamin-D content of the milk as it flows down the cylinder

Underwood & Underwood





Magnified globules of butterfat in cream[1]

Homogenized milk. When milk stands in a cool place, the cream rises to the top of the milk. In order to keep the cream uniformly dispersed throughout the milk, it is homogenized. This process makes the milk look and taste richer. No cream line will appear in the neck of a bottle of homogenized milk. The homogenization of milk is the process of forcing milk through very small holes under pressure at the time when it is heated to 140° F during pasteurization. This process breaks the globules of fat into minute particles and disperses them evenly throughout the milk. Because of their smallness, the fat particles are very slow in rising. The process of homogenization also tends to soften the curd of the milk.

Suggestions for the milk-consumer. It is advisable for every consumer to visit the dairy which produces his milk whenever possible. Ask to see the certificates of inspection showing that the milk has been certified. If your city maintains a laboratory and inspection service, get the ratings of all the dairies distributing milk in the city. Note particularly the bacterial count of the various brands of milk. You cannot take too many precautions in the selection of your milk. Milk is one of the most easily contaminated food commodities. The health of your family may be jeopardized by the milk it buys. If you live in a small town, visit the farmer who sells milk and note the sanitary conditions of his barns and milk house.

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[1] Reproduced from Cockefair and Cockefair's *Health and Achievement*, Ginn and Company.

Evaporated milk is safe because it is sterile. It has about half the water removed by evaporation and is homogenized. Where the sanitation of the milk supply is questionable, it is safer to use evaporated milk.

Condensed milk is milk which has been evaporated to half-volume and to which enough sugar has been added so that 40 per cent of the mixture is sugar. The Federal Food, Drug, and Cosmetic Act states that condensed milk must contain at least 28 per cent milk solids and not less than 8 per cent butterfat. It is very sweet and is used chiefly in cooking; when used in this way, it is diluted with water.

Dry milk is manufactured by evaporating all the water from whole milk. The Federal Food, Drug, and Cosmetic Act states that it must contain not less than 26 per cent butterfat and not more than 5 per cent moisture. None of the food solids, such as mineral matter and proteins, have been removed. When prepared from skimmed milk, the product is called "dry milk solids." Dry-milk products are widely used by candy-manufacturers and bakeries. Very little is sold to the retail trade.

Ice cream. There is no standardization for the manufacture of ice cream. This partly accounts for the great variation in price. Federal laws require that ice cream be wholesome, but they set no standard formula for manufacture. The quality of ice cream depends largely upon the integrity of the manufacturer. Some states and cities require that ice cream be made under certain sanitary conditions and from pasteurized milk and other specified ingredients. The quality of ice cream depends partly on the "overrun," or air, which is whipped into it. Air can be whipped into ice cream just as it can into eggs or ordinary cream. Cheap ice cream usually has a large amount of air and a small amount of cream. Average-quality ice cream is about 30 per cent air by volume. However, some ice cream may be as much as 60 per cent air which has been whipped into it.

Since there are few protective laws governing the manufacture and sale of ice cream, the consumer must be on his guard. Be sure that the containers in which the ice cream is kept are clean and well covered. The texture of the product should be smooth and uniform. There should be no noticeable "overrun," or air bubbles. The color should be natural and uniform. The flavors should be natural and pleasant.

E. I. Du Pont de Nemours & Co.

"Cellophane" is often used to seal milk bottles so that the milk may be kept in a sanitary condition

Butter. Butter is made from the fats of whole milk. The Federal government states that the minimum fat content of butter shall be 80 per cent. The United States Department of Agriculture provides for the grading of butter as follows:

The best grade	Special, or Dairy
The next-best grade	Extra, or Creamery
The third-best grade	Standard, or Packing Stock
The fourth-best grade	First, or Ladled
The lowest grade	Second, or Process

These terms mean little to the consumer. He should be sure that there is a statement on the carton to the effect that the butter is made of pasteurized milk. It should be neatly wrapped and placed in a clean carton. It should be cool when bought and should be kept in a refrigerator when not in use. "Sweet" butter means that the butter has not been salted. It may be made from sour cream. "Sweet cream" butter is made from pasteurized cream which was sweet up to the point where it was processed into butter. Most butter is made from sour cream. It has been pasteurized but has soured as a natural process in transporting and storage.

Cheese. In America cheese is made largely from cow's milk. When milk sours, lactic acid forms, and the casein (a protein) separates out as a solid. Most of the mineral salts and much of the butterfat remain with the solid protein matter. In making cheese, the liquid is drained and pressed from the solid material. The solids are then seasoned with salt, pressed into molds, and placed in storage for ripening. Certain bacterial and enzyme action takes place during this ripening process, giving the cheese a distinctive flavor. The holes in cheese are due to the evolution of carbon dioxide, caused by the bacterial and enzyme action. Different varieties of cheese are produced by the action of different bacteria.

Cheese may be classed as soft, semihard, and hard. Most cheese is made from whole milk. However, cottage cheese is made from skim milk. Cream may sometimes be added to cottage cheese. There are over three hundred and fifty different varieties of cheese on the market.

These men are making cheese from sour milk

Ewing Galloway

The most common cheese sold in grocery stores is American, or Cheddar, cheese. It is sold under different names according to style and shape. For example, "Longhorn" is five inches in diameter and weighs about twelve pounds.

Process cheese (artificially ripened cheese) is used extensively in making blended cheeses. Pineapple and pimento and other ingredients are often added to the process cheese. Process cheese is smooth in texture, lacking the holes which are caused by the gases produced during the ripening process in natural cheese. It is often sold in small packages or glasses.

EXERCISES

1. How can the consumer determine the quality of canned foods?
2. What are the various grades of canned fruits and vegetables? Is labeling according to grade compulsory? Why or why not?
3. What grades are the most satisfactory for most people?
4. What are the meanings of the grades which are established for fresh fruits and vegetables?
5. Describe the label which government inspectors put on wholesome meat.
6. What are the different grades of meat?
7. What are the chief characteristics of a good cut of beef?
8. What qualities should you look for in buying poultry?
9. How are eggs candled?
10. What are the differences between fresh eggs and preserved eggs?
11. How does water glass preserve eggs?
12. What is the composition of milk?
13. What grade of milk is the most satisfactory for ordinary use?
14. How is milk pasteurized?
15. Is vitamin-D milk necessary? Why or why not?
16. What is homogenized milk? How does it differ from ordinary milk?
17. What causes the disease trichinosis? How can it be prevented?
18. What are the differences between condensed milk and evaporated milk?
19. What precautions should you observe in buying ice cream?
20. How does cheese differ from butter?
21. How should cheese and butter be selected?

PROBLEMS FOR FURTHER STUDY

1. Make a study of "Cellophane." How has it contributed in making possible better and more sanitary food distribution?

2. How is candy adulterated?

3. How does your city health department protect your health by making and enforcing laws regulating the care and sale of foods?

4. What measures does your state take to protect the food produced and sold within its boundaries?

5. What evidence have you uncovered to indicate that food sold in your community is graded?

6. What are the advantages of quick-frozen foods?

7. Make a list of the various varieties of grains used as foods and state their most important uses.

8. What are the common dry breakfast cereals? Determine from what grains they are made and describe the process of manufacture.

9. What are the advantages of dried, or evaporated, foods? How are they made?

10. What are the common preservatives used in food, and what are the dangers of their use?

11. Make a list of spices and flavoring extracts and tell how they are obtained or manufactured.

12. What is cake color dye, and how is it made? Is it harmful?

13. How would you judge the quality of baked goods, such as pies and cakes? How should they be packaged?

14. How are fish marketed? Can you suggest precautions that the consumer should observe when purchasing fish and oysters?

15. How are jellies and jams usually adulterated?

16. Determine the best sizes of cans in which to buy the canned foods that you use. Take into consideration the size of the family, differences in price and weight of different-sized cans, and whether it is possible to keep unused portions in refrigerators.

17. How does the style of bottle cap affect the purity of the milk?

18. Make a list of common food adulterants and tell how you can detect them.

19. Make a study of the provisions of the pure-food laws referred to in Problem 2 and show how the consumer has been protected by the enactment of each provision.

20. Make a study of the inspection of milk as conducted by your city or state health department. What factors are considered in testing milk for purity?

21. What evidence do you find that the labeling and grading of food sold in your community are of definite value to the consumer?

UNIT EXERCISES

Some of the statements which follow are true, and others are false. On a separate sheet of paper write the word *true* for those which are true and the word *false* for those which are false. Do nothing for those about which you are doubtful. Rewrite the false statements so that they are true.

1. Modern commercial refrigeration has added much variety to the diet of the average person.

2. Packaging with "Cellophane" protects food from oxidation.

3. Packaged foods are more healthful than unpackaged foods.

4. Modern packaging with "Cellophane" protects food from germs.

5. The "dynamite" which is added to partially decomposed meat to make it appear fresh is generally $NaNO_3$.

6. The Food, Drug, and Cosmetic Act of 1938 prohibits the sale of food which may be injurious to health.

7. The law mentioned in No. 6 permits the use of coal-tar colors in foods.

8. This law requires that the labels on packaged foods contain a correct statement of the weight or the numerical count of its content.

9. This law does not give the government the right to prosecute manufacturers who put unclean food in cans.

10. This law sets up standards to which all food-manufacturers must conform.

11. Most state laws are inadequate for complete protection in the purchasing of food.

12. Commercially canned fruits and vegetables do not have the food value of home-canned fruits and vegetables.

13. The quality of canned foods can easily be told by the attractiveness of the labels.

14. Higher-priced canned foods are of better quality than those of lower price.

15. Extra Standard, or Choice, is the best, or A Grade, of canned food.

16. Most canned foods are of Grade C quality.

17. U.S. Off Grade, or Substandard, is the lowest grade of canned food.

18. A No. 2 can holds about four cups of food.

19. The highest grade of fresh fruits and vegetables is known as U.S. Fancy.

20. The United States stamp of approval on meat guarantees that the meat is of the highest quality.

21. The highest grade of meat is known as Choice.

22. A good cut of meat will have a marbling of fat in it.

23. Trichinosis is a disease of human beings, caused by eating uncooked beef.

24. U. S. Prime is the best grade of poultry.

25. Eggs are a good source of vitamins A, B_1, B_2, and D.

26. Eggs which carry the grade label of AA Special are the highest quality that you can buy.

27. Eggs cannot be preserved for any length of time.

28. Most whole milk contains from 2 per cent to 3½ per cent fat.

29. Milk is 87 per cent water.

30. All milk should be pasteurized.

31. Grade B milk differs from Grade A milk in that it contains fewer bacteria.

32. Vitamin D may be added to milk by subjecting it to ultraviolet rays of light.

33. Milk to which vitamin D has been added is known as eradicated milk.

34. Homogenized milk contains larger fat globules than ordinary milk.

35. Evaporated milk is likely to be contaminated.

36. Condensed milk always has a great deal of sugar added to it.

37. Dried milk is used in candymaking and in many bakeries.

38. There is no standardization of ice cream.

39. Ice cream to which air has been added is just as nutritious as that to which no air has been added.

40. Sweet butter is that which is made from sweet cream.

41. Cheese is made from the fats in milk.

42. Cheese may be made by adding bacteria to skim milk.

43. Most butter is made from sour cream.

44. Candy is easily adulterated with artificial flavors and artificial sweetening agents.

45. Cheese may be artificially ripened.

REFERENCES FOR FURTHER READING

Beery, Pauline G. *Chemistry Applied to the Home and Community.* J. B. Lippincott Company, Philadelphia, 1926.

Bolduan, Charles F., and Bolduan, Nils W. *Public Health and Hygiene.* W. B. Saunders Company, Philadelphia, 1937.

Brindze, Ruth. *How to Spend Money.* The Vanguard Press, New York, 1935.

Eaton, Jeanette. *Behind the Show Window.* Harcourt, Brace and Company, New York, 1935.

Ehlers, V. M., and Steel, E. W. *Municipal and Rural Sanitation.* McGraw-Hill Book Company, Inc., New York, 1937.

Monroe, Day, Kyrk, Hazel, and Stone, W. B. *Food Buying and Our Markets.* M. Barrows & Co., Inc., New York, 1938.

Reich, Edward, and Siegler, C. J. *Consumer Goods.* American Book Company, New York, 1937.

Steel, E. W., and White, E. G. *Hygiene of Community, School, and Home.* Harper & Brothers, New York, 1937.

Better Buymanship Leaflets: No. 1, *Poultry, Eggs, and Fish;* No. 3, *Fruits and Vegetables;* No. 6, *Meat;* No. 11, *Dairy Products;* No. 22, *Food Fats and Oils.* Household Finance Corporation, Chicago, 1938.

Buying Guide, Consumers Union, 17 Union Square West, New York, 1939–1940.

Consumers Guide, Consumers Council, Agricultural Adjustment Administration, United States Department of Agriculture, Washington, D.C.

General Bulletins, Consumers Research, Washington, New Jersey, 1939–1940.

UNIT 32

Chemistry in Industry

There are many who would have you believe that living in "the good old days" of fifty years ago was more pleasant and interesting than it is today. A study of conditions then and now reveals that such a belief is based on sentiment rather than facts.

The family of fifty years ago was largely self-sustaining. Almost everything that was needed for living was produced in the home. The family was continually struggling for necessities, and little time was left to enjoy luxuries or to participate in activities which help to make life worth living.

Most of those who sing the praises of "the good old days" would be unwilling to exchange living today for living in the past. They fail to recognize the large part that the many discoveries and inventions play in our lives today. Who among them would be willing to give up the telephone, the radio, the automobile, the modern home, and a score of other things and return to the past?

Industry deserves much credit for making present-day living comfortable, pleasurable, and satisfying. It has done much to make the new inventions and discoveries usable and of service to man. Industry has produced devices, such as electric washing machines, tractors, and sewing machines, which have reduced the drudgery of work. Mass production, a result of the machinery produced by industry, has reduced the laboring day from twelve to as few as six hours. Industry not only has given us time for recreation but has provided us with ways and means of enjoying our leisure time. The automobile, radio, motion picture, and television are products of industry. Life would really be a dull affair without the help of industry.

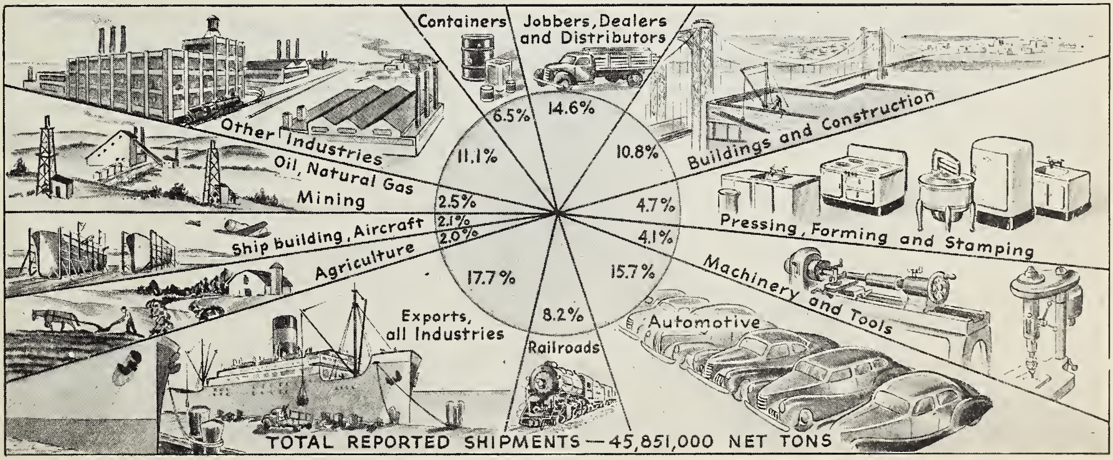
Many industries have been discussed and referred to earlier in this book. The purpose of this unit is not to discuss all industries but to stress some important ones which merit further discussion.

PURPOSES TO BE ACHIEVED

1. To acquaint you with some of the important modern industries.
2. To help you to appreciate the contributions that industry has made to present-day living.
3. To familiarize you with the chemist's methods of controlling industrial processes.

Distribution of steel to consuming industries in 1940

Steel Facts



Ford Motor Company

This composite picture shows some of the many steps involved in the making of iron and steel. How many of the processes can you identify?

PROBLEMS TO BE SOLVED

1. What are the manufacturing processes involved in each industry?
2. What vitally important products are produced by each industry?
3. What is the chemical nature of each product?
4. What information about the products of industry is valuable to the consumer?

The problems listed above will be discussed under each of the following industries:

1. Iron-and-steel industry
2. Alloy industry
3. Rubber industry
4. Petroleum industry
5. Explosive industry
6. Sugar industry
7. Plastics industry
8. Electrochemical industry

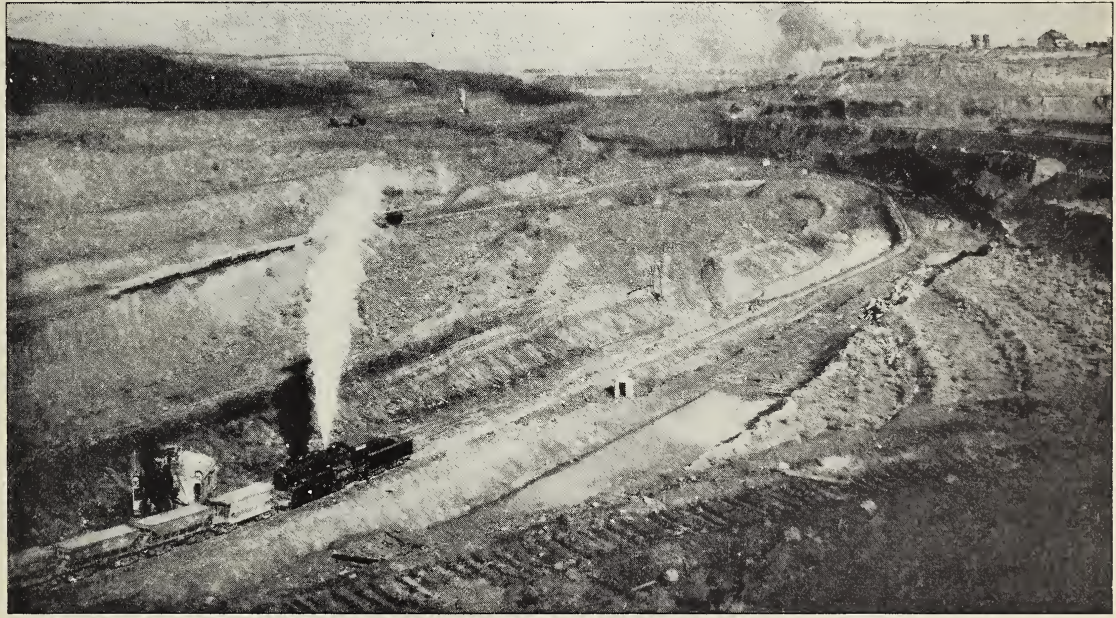
The Iron-and-Steel Industry

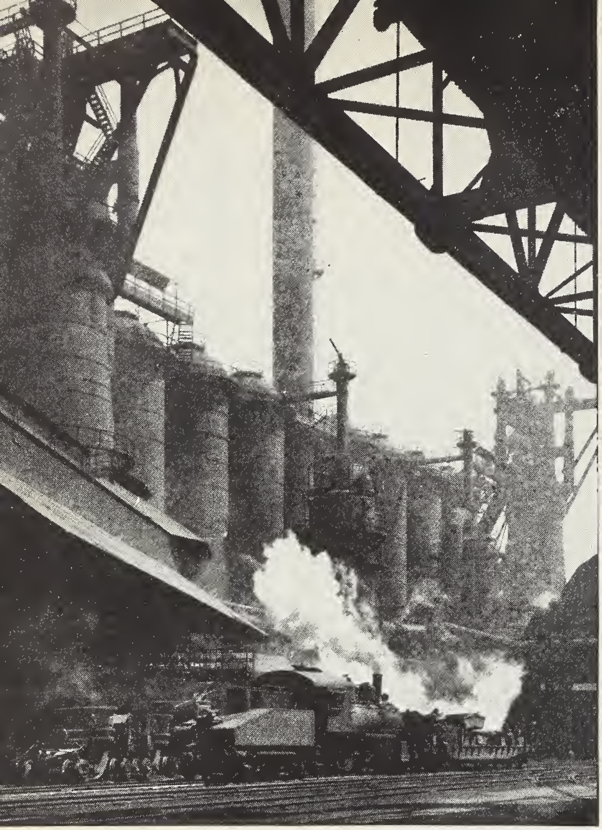
The skeleton materials of industry. Iron and steel are more valuable to man than gold. These metals bear the burden of our tremendous industrial age. Giant skyscrapers are possible because of the strength of the steel beams which hold the brick and cement in place. Huge bridges which support the traffic of the nation are made of steel. The engine, frame, and body of your car are made of special alloyed steel. The safety of passengers in swift-moving trains drawn by powerful steel locomotives over steel rails is assured only because of the tremendous strength of this metal. Giant steam shovels made of steel excavate places for the foundations of huge concrete dams—dams which are held together by a network of steel bars. All the machines used in the many factories which produce the goods of this modern world are made of steel.

Iron from iron ore. Fortunately iron compounds are abundant in nature. The ores most rich in iron are hematite (Fe_2O_3) and magnetite (Fe_3O_4). Since iron is relatively high in the activity series of the elements, it never occurs in its natural state. To get the metal, man must rob the ore of the oxygen with which it united millions of years ago. This is essentially a chemical process. The reduction of iron from its ore is one of the major industries of this country.

An open-pit iron mine in the Mesabi Range, in Minnesota

United States Steel Corporation





Carnegie-Illinois Steel Corporation

A unit of two blast furnaces with their hot blast stoves for heating the 7000 tons of air forced into the two furnaces each day

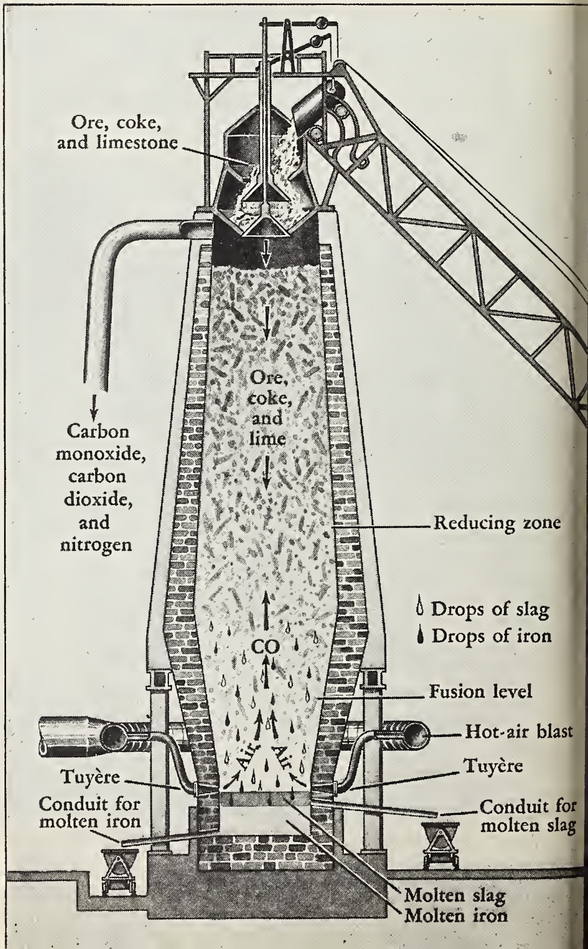
The principal iron-ore deposit of the United States is in the Mesabi Range about eighty miles east of Duluth, Minnesota. In the Mesabi deposit, huge steam shovels scoop up the hematite and place it in cars. It is then carried to Duluth, where it is loaded onto boats on Lake Superior. These boats carry the ore to steel mills located in such cities as Gary, Chicago, Detroit, and Cleveland.

The blast furnace. The reduction of the iron ore takes place in large vertical cylindrical structures called blast furnaces. These furnaces are about 100 feet high and are lined with firebrick. Their operation is continuous; they shut down only when repairs are necessary. A furnace will produce about 700 tons of cast iron each day.

The charge consists of carefully calculated amounts of (1) ore, hematite (Fe_2O_3), (2) a reducing agent, coke (C), (3) a flux for removing impurities, limestone ($CaCO_3$), and (4) hot air (O_2). Alternate layers of ore, coke, and limestone are admitted into the furnace through a special device in the top which prevents the escape of the hot gases. The hot air is admitted under pressure to the furnace through pipes called tuyères. These pipes are located near the base of the furnace. The coke in the bottom of the furnace burns to form CO_2. This gas goes up through the charge, comes in contact with white-hot carbon, and is reduced to carbon monoxide (CO). The carbon monoxide then reacts with the ore (Fe_2O_3) and forms metallic iron and carbon dioxide. Some of the hot carbon also reduces the ferric oxide to molten iron, which trickles to the bottom of the furnace.

The reactions which take place in the blast furnace are complex but may be represented by the following equations:

Cross-sectional diagram of a typical blast furnace



$$C + O_2 \longrightarrow CO_2\uparrow$$
$$C + CO_2 \longrightarrow 2\,CO\uparrow$$
$$Fe_2O_3 + 3\,CO \longrightarrow 3\,CO_2\uparrow + 2\,Fe$$
$$Fe_2O_3 + 3\,C \longrightarrow 3\,CO\uparrow + 2\,Fe$$

Most iron ore contains sand (SiO_2) as an impurity. In order to remove this sand a flux is added which will unite with it to form a molten liquid called slag. The lighter slag floats on the surface of the heavy molten iron. The equations for these reactions are as follows:

$$\overset{\text{limestone}}{CaCO_3} + \text{heat} \longrightarrow CaO + CO_2\uparrow$$
$$\overset{\text{lime}}{CaO} + \overset{\text{sand}}{SiO_2} \longrightarrow \overset{\text{slag}}{CaSiO_3}$$

The air which enters the furnace is preheated in "stoves." The stoves are heated by the hot combustible gases which leave the furnace near the top.

Cast iron. The molten iron and slag collect at the bottom of the furnace. First, the light slag is drawn from the top of the molten iron about every four hours. Then the iron is run into large fire-clay-lined ladles which run on tracks and are carried to other furnaces, where the molten iron is made into steel. It may be run into small molds and cast into "pigs." These pigs are bars about 18 inches long; when cooled, they may be stored for future use.

Cast iron contains about 4 per cent carbon and 2 per cent other substances, such as silica, phosphorus, manganese, and sulfur.

Cast iron is gray in color, hard, and very brittle. It will sustain a very heavy load but will break if subjected to a sudden shock. It cannot be welded or tempered like steel. It is used in making the bases of some machines, ornamental city light posts, stoves, and radiators for heating systems. Most of the cast, or pig, iron which is produced is used in making steel.

Steel. Steel is a purer form of iron than cast iron. The impurities of cast iron make it brittle and therefore limit its uses greatly. Steel is made by removing the impurities of cast iron and regulating the carbon content. The chief impurities of cast iron (carbon, sulfur, and phosphorus) are removed by oxidation. Any silica is removed by the addition of a flux. Steel is usually made by the Bessemer process or the open-hearth process.

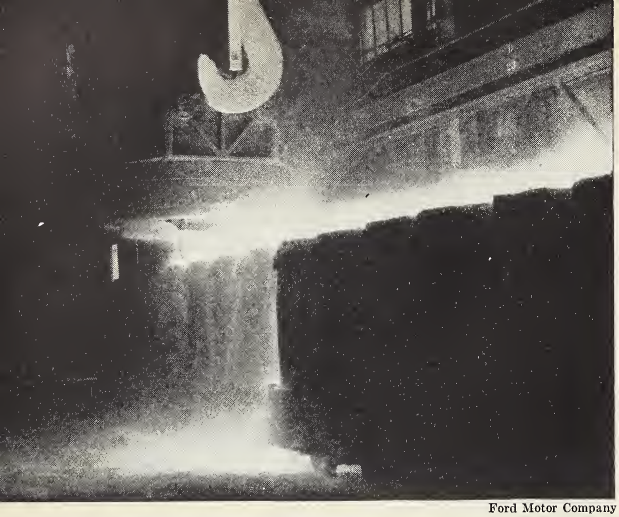
Carnegie-Illinois Steel Corporation

One hundred tons of blast-furnace iron being poured into an open-hearth furnace to be converted into steel

The Bessemer process. The Bessemer converter is pear-shaped and rests on an axle which makes it possible for the molten steel to be poured out after the reaction is complete. It is filled with about 25 tons of molten cast iron from the blast furnace.

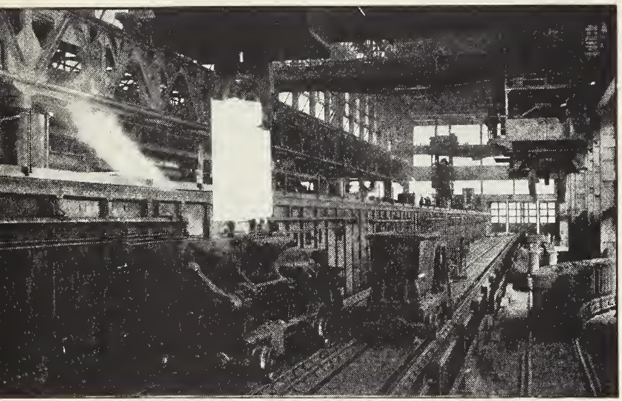
After the steel has run from the furnace into the ladle, the lighter slag follows. Here the slag is running out and will soon overflow into a special ladle called a thimble. The bar at the right is the stopper rod, by which the stopper at the bottom of the ladle is raised and lowered to permit the pouring of the steel into ingots

American Iron and Steel Institute



Ford Motor Company

Molten steel from an open-hearth furnace being poured into molds to form ingots

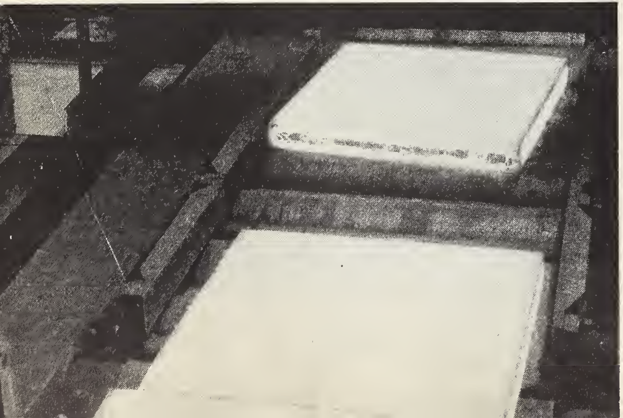


Ford Motor Company

A white-hot steel ingot starts its journey through the blooming mill, which will roll it into thin sheets

Slabs of white-hot steel, each weighing 5000 pounds, being rolled in a blooming mill. These giant machines are electrically operated by men in control rooms

United States Steel Corporation



A blast of hot air is sent up through the molten cast iron, thus oxidizing, or burning out, the impurities. The excess carbon, sulfur, and phosphorus unite with the oxygen to form gaseous oxides, which escape in a roaring flame into the air. The reaction is completed in about 15 minutes, and is regulated by an operator who tells by the changes in the color of the flame and by its size when the reaction is complete. This is very inaccurate, and therefore the quality of the steel produced by this method varies considerably. The SiO_2 in the cast iron unites with some of the CaO and MgO in the lining of the converter to form slag. It floats on the steel and can be skimmed off.

The open-hearth process. In the open-hearth process the impurities of cast iron are oxidized by the addition of rusty scrap iron and iron oxide ore. The furnace is a large rectangular structure made of steel or firebrick and lined with firebrick, dolomite, and magnesite. The furnace is kept hot by burning a gas with preheated air. The sulfur, carbon, and phosphorus unite with the iron oxide, forming the oxides SO_2, CO, and P_2O_5. The SiO_2 unites with limestone, which is added, or with the lining of the furnace to form the slag $CaSiO_3$. The P_2O_5 unites with the CaO to form CaP_2O_6, which forms another ingredient of the slag. The open-hearth furnace will make about 70 tons of steel every six to twelve hours. Since the reaction takes place over such a long period of time, it is possible to make an accurate chemical analysis of the charge at frequent intervals. In this way a uniform product is assured. Most of the steel in use today has been made by this process.

The properties of steel. Steel is an alloy of iron and carbon. The carbon content may run from 0.2 per cent in soft steel to 1.5 per cent in hard steel. The higher the carbon content, the harder the steel. Steel is elastic and tough, and will withstand sudden shock and vibrations to a high degree. It may be welded and tempered. For these reasons steel finds a wide variety of uses.

Tempering steel is accomplished by heating it to different temperatures and cooling it at different rates. Both these factors affect its hardness, or temper. If it is heated to a cherry red and suddenly cooled by being plunged into cold water, the molecular structure becomes such that the steel is very hard. If it is allowed to cool more slowly, the structure is different and a softer steel results.

Wrought iron is made from cast iron by a process somewhat similar to the open-hearth process of making steel. Practically all the impurities are removed, and a very soft product, called wrought iron, is made. Wrought iron is very tough and malleable, and can be bent and welded. It is used in the manufacture of chains, wire, bolts, nails, and ornamental hammered objects. Wrought iron is being replaced by a special soft low-carbon steel.

EXERCISES

1. Why are iron and steel important to man?
2. What are the principal ores of iron? From what locations are they obtained?
3. Of what does the charge of a blast furnace consist?
4. Describe fully the action of the blast furnace. Use equations to show the chemical reactions which take place.
5. What is the final product of the blast furnace? What is the composition of this product? What uses are made of it?
6. What is steel? How does it differ chemically from cast iron?
7. Describe the Bessemer process of making steel.
8. Describe the open-hearth process of making steel.
9. What are the properties of steel?
10. How is steel tempered?
11. What is wrought iron? What uses are made of it?

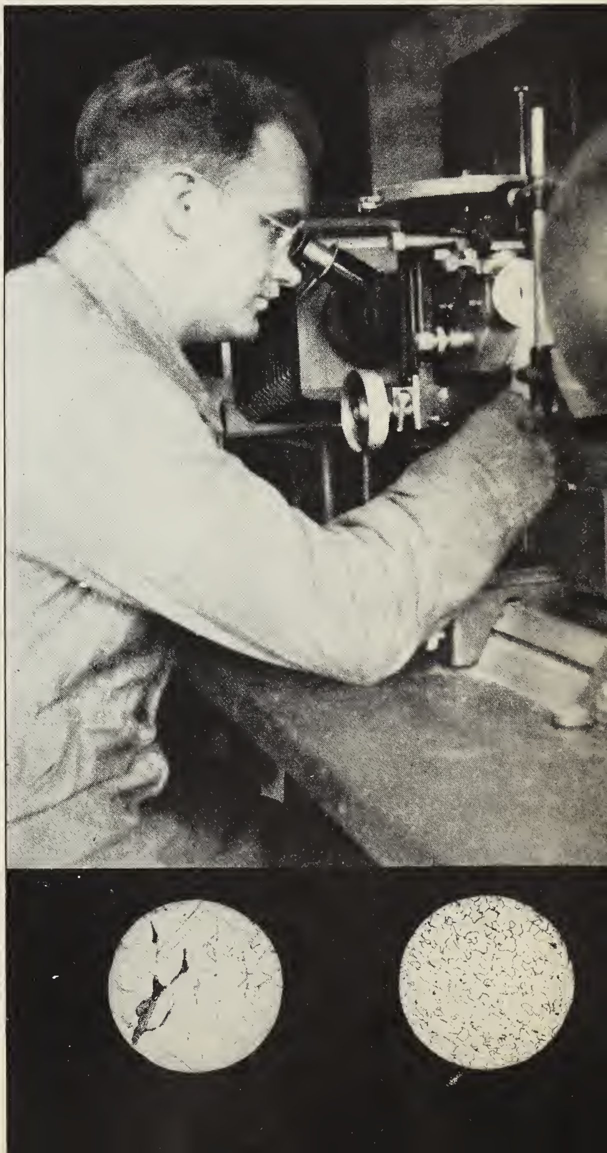
The Alloy Industry

What is an alloy? When metallic elements are melted together, the substance formed is called an alloy. It is, of course, essential that these elements be soluble in each other when molten. Thus, when iron and carbon are melted together in the correct proportions, steel is produced. Copper pennies are made of copper, tin, and zinc, and sterling silverware is made of silver and copper.

How important are alloys? You have been told that we are living in a machine age. It could well be called a metallic age because metals are necessary to make machines, and many of the products of machines are made of metals. In any event, think of the many things that you use every day, and you will realize that most of them either are made of

Microscopes are the "eyes" of metallurgists. Microscopic examination is an important part of the quality-ensuring routine of steel manufacture. A microscope reveals that steel is a mass of tiny grains. The rolling and the various heat treatments to which steel is subjected during manufacture change the shape and arrangement of these grains. Some of these changes make for better steel, but others may prove harmful if not corrected. The two photomicrographs (each a cross section of steel magnified 100 times) show how steel may look before and after rolling. The picture on the left was taken before the steel was rolled, whereas the one on the right shows the same metal after having been rolled into a thin sheet. The light areas are pure iron; the darker ones are a mixture of iron, carbon, and other elements

American Iron and Steel Institute



metals or are made by machines that are made of metals.

Very few objects are made of pure metal. This is due to the fact that pure metals rarely have the properties required of them. A burglarproof safe requires a metal which is hard and which can withstand a sudden shock. Pure iron is soft and cannot meet these requirements, but an alloy of iron and manganese has both the necessary properties.

Many of the things that we use require metals with special properties. Because pure metals rarely have these properties, industries have been forced to produce thousands of alloys. New alloys are constantly being made. Industries are spending millions of dollars for research in the attempt to find the best possible alloys for the products that they are making.

What determines the properties of alloys? Some metals, such as gold and silver or copper and zinc, when melted together, form a true solid solution. Others, such as iron and carbon or aluminum and copper, form definite compounds (Fe_3C, AlCu), which usually separate in the form of small crystals. In still other alloys the elements crystallize separately. This is true of an alloy of cadmium and bismuth. Many alloys are a combination of two or three of those described above.

It is almost impossible to predict the properties of an alloy, though the properties of the metals used in making it are known. Because of this fact, it is often possible to obtain an alloy that has properties much more desirable than the combined properties of the component metals.

In general, the density of the alloy is the average density of the component metals; the alloy is harder than the component metals; its melting point is lower than that of any of the component metals; it is a poorer conductor of electricity than the component metals; its color is not predictable.

If iron is one of the constituents of an alloy, the alloy is classified as ferrous (from the Latin *ferrum*, meaning " iron "); if no iron is present, the alloy is said to be nonferrous.

Ferrous alloys. The development of high-speed machinery has necessitated the production of special alloys which will withstand unusual strain and abuse. If from 3 per cent to 4 per cent nickel is added to steel, it becomes exceedingly tough and corrosion-resistant. Nickel steel is used in making the armor plate of modern battleships. Stainless-steel cutlery is made from a chromium-steel alloy. Manganese-steel alloys are used in railroad switches and crossings because of their hardness and ability to withstand sudden shocks. They are also used in making burglarproof safes.

Vanadium steel is used in making automobile springs and axles. Many high-speed tools are made from molybdenum and tungsten steel.

"Duriron" contains silicon and resists corrosion. Pipes made of "Duriron" are used to convey many chemicals in industrial plants. The pipes from laboratory sinks are often made of "Duriron."

Nonferrous alloys. There are many alloys made from metals other than iron. Some of the more common ones, with their composition and uses, are listed in the table at the foot of the page.

EXERCISES

1. What is an alloy? Give examples.
2. Discuss the importance of alloys.
3. What determines the properties of an alloy? Discuss fully.

Common Name	Approximate Composition	Use
Babbitt metal	Sn 90%, Cu 3%, Sb 7%	Machine bearings
Brass	Cu 67%, Zn 33%	Hardware, pipes
Bronze	Cu 95%, Zn 4%, Sn 1%	Coins, statuary
"Duralumin"	Al 95%, Cu 4%, Mg 1%	Airplane framework
German silver	Cu 46%, Zn 34%, Ni 20%	Tableware
Lead (shot)	Pb 99.8%, As 0.2%	To fill shotgun shells
Monel metal	Ni 60%, Cu 33%, Fe 6.5%	Sink drains and boards, plumbing fixtures
Pewter	Sn 85%, Cu 6.8%, Bi 6%, Sb 2%	Dishes and ornaments
Solder	Pb 67%, Sn 33%	For soldering
Type metal	Pb 70%, Sb 18%, Sn 10%, Cu 2%	Type for printing
Wood's metal	Bi 50%, Sn 12.5%, Pb 25%, Cd 12.5%	Automatic fire sprinklers. (Low-melting alloy—melts at 65° C)

4. What are ferrous alloys?

5. Name some common ferrous alloys. How are they made? What use is made of each?

6. What are nonferrous alloys?

7. Name several nonferrous alloys. Give the composition and use of each.

The Rubber Industry

Source of rubber. The raw material from which rubber is extracted is a milky, sticky fluid called latex, obtained from the rubber tree, of which there are many varieties.

The latex from which rubber is derived has been known for thousands of years. It was first used to waterproof fabrics. Columbus brought balls made from it back to Spain when he returned from the New World.

Most of the world's supply of this latex and rubber has been obtained from the Netherlands Indies and near-by countries, where the industry has grown to huge proportions.

Latex is obtained by cutting narrow strips from the bark of the rubber tree. A metal spout carries the latex, which exudes from the tree, to porcelain cups, which are emptied every day.

Obtaining rubber from latex. Rubber was first extracted from latex by dipping wooden paddles in the latex and holding them over a smoky fire to evaporate the water. When this process was repeated, a heavy coating of rubber formed. This raw rubber was then cut off the paddles, bound in bales, and shipped to rubber-manufacturers. This method has been replaced by several more efficient processes. When an acid, such as acetic acid or formic acid, is added to latex, the rubber is coagulated. Rubber extracted in this manner is washed and dried in air or by being smoked. Rubber may also be obtained from latex by spraying the liquid into a hot chamber. The heat evaporates the water, and the droplets of rubber fall to the floor of the chamber. The raw rubber obtained by any of these methods has but little use. To be of practical value it must be vulcanized.

The use of latex. Some of the latex produced on rubber plantations is shipped to manufacturers. To keep the rubber from coagulating, ammonia is added to the liquid.

United States Rubber Company

This operator in a rubber-manufacturing plant is not pouring a huge flapjack, as it might appear. The whipped latex batter which he is pouring into a mold will soon become a mattress

Latex has a wide variety of uses. It is especially useful in the making of articles that require a thin coating of rubber. Rubberized fabrics are made by dipping the fabric in latex and vulcanizing the product. Toy balloons, rubber gloves, and other thin-layered rubber articles are made by depositing electrically the rubber from latex on a metal form. In making a rubber glove, a metal hand of the desired size is attached to the negative electrode. Automobile-tire manufacturers have discovered that cord made from threads dipped in latex is much stronger and more lasting than plain cotton cord.

Making raw rubber useful. Raw rubber has little strength, durability, or stretching quality. Rubber acquires these qualities when it is vulcanized, that is, mixed with sulfur and heated. Before the raw rubber is so treated, it is thoroughly washed and then dried. Chemicals, such as carbon, sulfur, litharge (PbO), zinc oxide (ZnO), magnesium carbonate ($MgCO_3$), and whiting ($CaCO_3$), are thoroughly mixed with the rubber by kneading the mixture between large rollers. The selection of the ingredients to be mixed with the rubber depends on the quality of rubber desired and the use that is to be made of it. Lead compounds act as an accelerator by hastening the vulcanizing process.

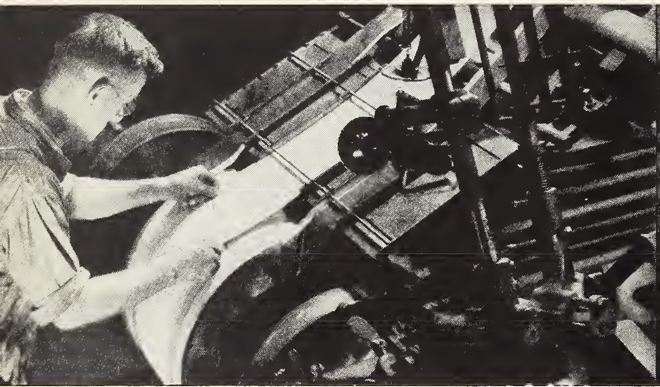
After thorough mixing, the rubber is either rolled into sheets of desired thickness or rolled into the meshes of fabric. It is then shaped or molded into

B. F. Goodrich Company

This tapper is at work on a tree in a rubber plantation. Note how carefully the cuttings have been made on the tree. Too-deep cuts would wound them

B. F. Goodrich Company

Washing crude rubber preparatory to processing



B. F. Goodrich Company

Building a pneumatic tire. Years of experimentation and experience go into making tires much more durable and safe

B. F. Goodrich Company

Tires are placed in molds preparatory to vulcanization. The tread design is formed by these molds as the tires are vulcanized

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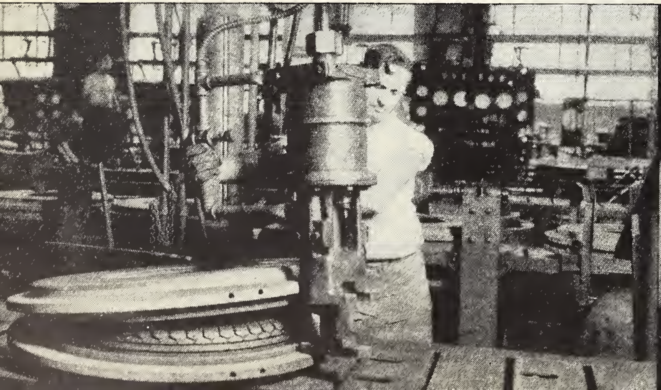
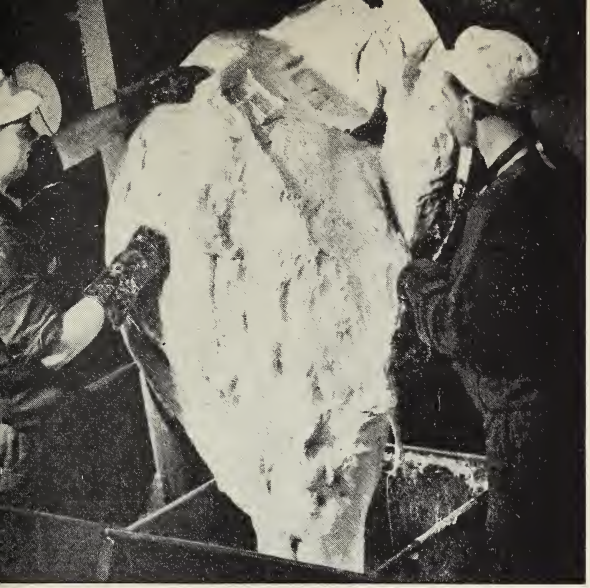
Removing a tire from a mold after vulcanization

B. F. Goodrich Company



This engineer is examining the conditions inside a speeding tire with a fluoroscope

United States Rubber Company



E. I. Du Pont de Nemours & Co.

These operators have transformed chemically a free-flowing liquid into a doughlike mass of neoprene—man-made rubber

the manufactured articles. The shaping or molding of some articles is done by machinery, whereas other articles must be made by hand. The article is usually heated to a temperature of from 200° F to 285° F while still in the mold. This heating process is known as vulcanization. Vulcanized rubber is strong, durable, and elastic.

Synthetic rubber. The entrance of the United States into the second World War has practically eliminated the importation of crude rubber from the East Indies. In fact, the supply of natural rubber obtained from all sources has decreased from over 800,000 tons in 1941 to an estimated importation of 130,000 tons in 1943.

Fortunately, the production of synthetic rubber in the United States had been started prior to the beginning of the war. The present and future demand for rubber for mechanized equipment and materials for warfare and civilian use must necessarily be met largely through increasing the production of synthetic rubber. In 1942 about 25,000 tons of synthetic rubber was made and if production schedules are adhered to, it is estimated that 400,000 tons will be manufactured in 1943. By producing this amount of rubber synthetically and by conserving the crude rubber supply now on hand, government officials believe that the demands of manufacturers of war materials and equipment for rubber can be met.

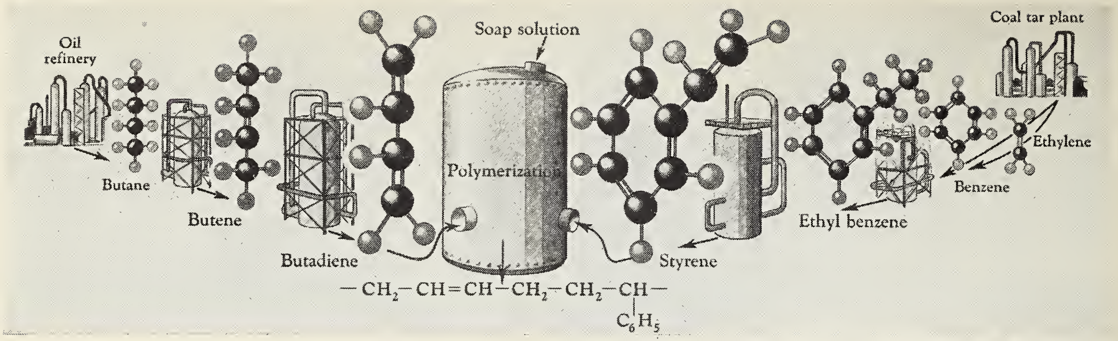
Natural rubber is not a simple compound. Although its exact composition is not known, rubber is supposed to be composed of exceptionally large molecules which are built up from the hydrocarbon isoprene (C_5H_8). Chemists have been able to produce substances whose molecules are similar to isoprene and from which substances have been produced having chemical and physical properties similar to natural rubber. These substances are known as synthetic rubber.

There are several methods of making synthetic rubber. Each kind of rubber made by these methods varies slightly in chemical composition. The present war production schedule calls for most of the synthetic rubber to be made from petroleum and coal while some may be made from alcohol and coal. Most of the synthetic rubber made from these materials is called Buna-S. In addition to Buna-S, Neoprene from acetylene and butyl rubber from petroleum, two other kinds of synthetic rubber, are being produced on a smaller scale.

The Buna-S Process. The raw materials necessary for the making of synthetic rubber by this process are three relatively simple hydrocarbons—butane, C_4H_{10}; ethylene, C_2H_4; and benzene, C_6H_6. In America butane, a by-product of the refining of gasoline, is obtained, largely, from oil refineries. However, butane can be obtained from alcohol, made either from grains, potatoes, or sugar. It can even be made from acetylene (C_2H_2), which has as its raw materials coal and limestone; however, this latter process is more expensive. Ethylene

Synthetic rubber is now used in making household gloves. Oil causes natural rubber to deteriorate much more rapidly than synthetic rubber. The furniture polish that this woman is using will have little effect on her synthetic rubber gloves

E. I. Du Pont de Nemours & Co.



Based on a drawing by Herbert Bayer for *Fortune* magazine

The process for making Buna-S

and benzene are products of the coal-tar industry, but they too may be made from other sources.

These three hydrocarbons must undergo many processes and chemical changes before the Buna-S type of synthetic rubber can be made from them. Such chemical reactions are not simple and involve the use of catalysts and delicate temperature and pressure controls. However, the main reactions in the processes involved in making Buna-S can be understood through careful study of the flow diagram above. In interpreting this diagram you must start at both ends and work toward the middle, where the reactions end in the product Buna-S.

Starting at the left, butane (C_4H_{10}) is made into butylene (C_4H_8); butylene is then made into butadiene (C_4H_6). A study of these formulas shows that these successive processes involve the removing of hydrogen from the hydrocarbon molecules. This is known as dehydrogenation.

Now from the right, ethylene (C_2H_4) and benzene (C_6H_6) are combined to make ethylbenzene. Ethylbenzene is then put through a cracking process which converts it into a compound known as styrene ($C_6H_5{-}CH{-}CH_2$). The styrene and the butadiene are then interpolymerized (a building-up process) in a soapy emulsion to which a catalyst has been added. The final product resulting from the interpolymerization of styrene and butadiene is a rubbery mass known as Buna-S. The chemical composition of this type of rubber is similar to that of natural rubber and its molecules are made up of giant chains of molecules of $C_{10}H_{16}$ or some multiple of $C_{10}H_{16}$.

The Petroleum Industry

Source of petroleum. The exact origin of petroleum is not known. It is supposed to come from decayed animal and vegetable matter which was covered up millions of years ago by sand and soil. Some scientists believe that petroleum was formed through an inorganic reaction in which carbon compounds united with hydrogen.

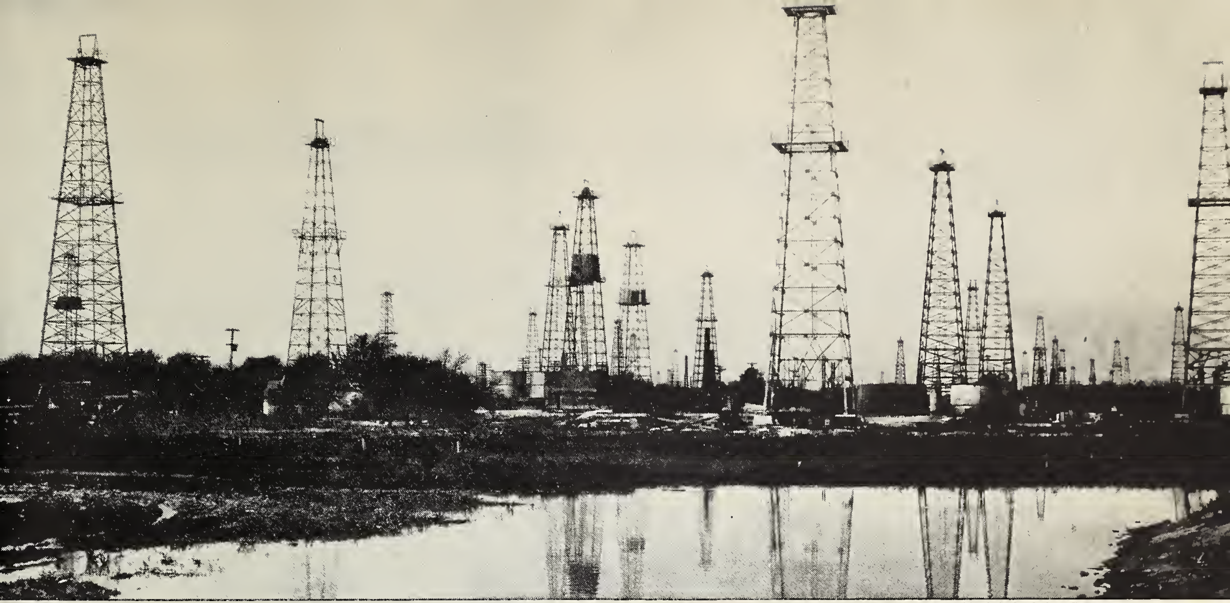
Although crude oil has been discovered flowing from the surface of the ground, it is usually found in pockets far below the surface. Petroleum is found widely distributed over the face of the earth. Many sources have not yet been tapped. The first oil well in the United States was drilled in Pennsylvania in 1859 by Colonel Edwin L. Drake.

The first crude oil was used to anoint the skin and for medicinal purposes. Until the invention of the automobile, its use was very limited. Today over a billion barrels of petroleum is being produced every year.

The chemical nature of petroleum. Petroleum is a mixture of the hydrocarbons of the methane series. You will recall that this series has the general formula C_nH_{2n+2}. The first few compounds of this series are

Methane.	CH_4	Hexane	C_6H_{14}
Ethane	C_2H_6	Heptane	C_7H_{16}
Propane	C_3H_8	Octane	C_8H_{18}
Butane	C_4H_{10}	Nonane	C_9H_{20}
Pentane	C_5H_{12}	Decane	$C_{10}H_{22}$

This series contains many more compounds than are listed here. The first four are gases, the next ten



Sinclair Refining Company

A forest of oil derricks in a Texas oil field

are liquids, and the compounds that contain more than sixteen carbon atoms are solids.

Petroleum is composed of many useful substances. Naphtha, gasoline, benzine, kerosene, fuel oil, lubricating oils, paraffin, "Vaseline," and other products are mixtures of the hydrocarbons contained in crude oil. These are extracted from it by refining.

Refining petroleum. Petroleum is refined by distillation. The crude petroleum is pumped into a still, and heat is applied. When the temperature is raised to 200° C, the gasoline, benzine, and naphtha are distilled off and condensed. This distillate is called a fraction, which must be redistilled to obtain each of the products named. If the temperature is raised to 300° C, the kerosene distillate will be obtained. As the temperature is further increased, the products obtained, in order, are fuel oil, lubricating oil, "Vaseline," and paraffin. Other products coming from the distillation are asphalt and petroleum coke.

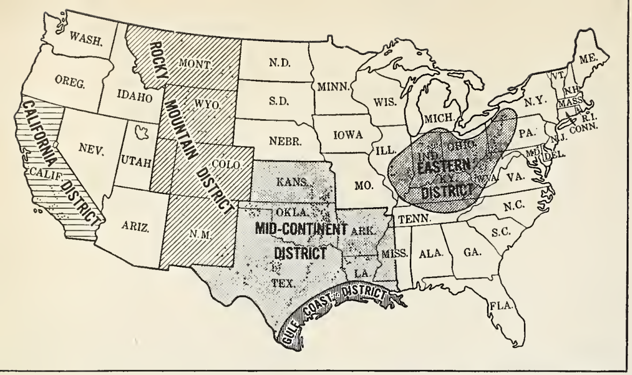
Gasoline. Gasoline is not a single compound. It is chiefly a mixture of hexane (C_6H_{14}) and heptane (C_7H_{16}). Its value in the gasoline engine is due to the inflammability of a mixture of its vapor and air.

A barrel of crude oil (42 gallons) yields about 15 gallons of gasoline in the distillation process. The tremendous increase in the number of automobiles has created a demand for gasoline beyond normal production. For this reason chemists have had to discover methods of obtaining more gasoline from petroleum. The two processes now being used to do this are cracking and polymerization.

Cracking petroleum. You will recall that most of the hydrocarbons of the methane series have a greater number of carbon atoms in the molecule than gasoline has. If these compounds are distilled under pressure and high temperature, the larger molecules of the heavier, slower-burning hydrocarbons will be decomposed into the smaller, more volatile molecules of gasoline. Thus kerosene, fuel oil, "Vaseline," and other heavier hydrocarbons may

A tank farm for the storage of crude petroleum. Each tank has a capacity of 80,000 barrels

Sinclair Refining Company



American Petroleum Institute

Map showing oil fields in the United States

be "cracked" to gasoline by this process of destructive distillation.

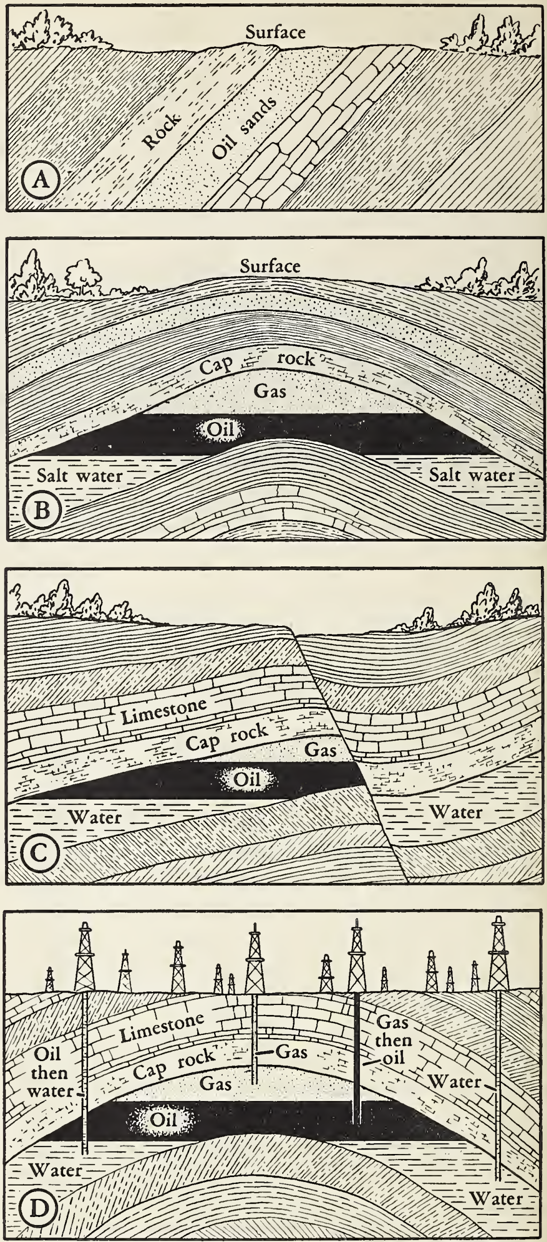
Polymerized gasoline is made by "building up" the molecules of the hydrocarbons that have less carbon per molecule than gasoline.

Casing-head gasoline is obtained by condensing the gas which is liberated from oil wells. It is a highly volatile gasoline.

Purchasing gasoline. Most gasoline which is sold today is a mixture of that made by straight-run distillation and by the cracking, polymerization, and casing-head processes. There are two terms used in relation to gasoline which everyone should understand. They are *antiknock* and *octane rating.*

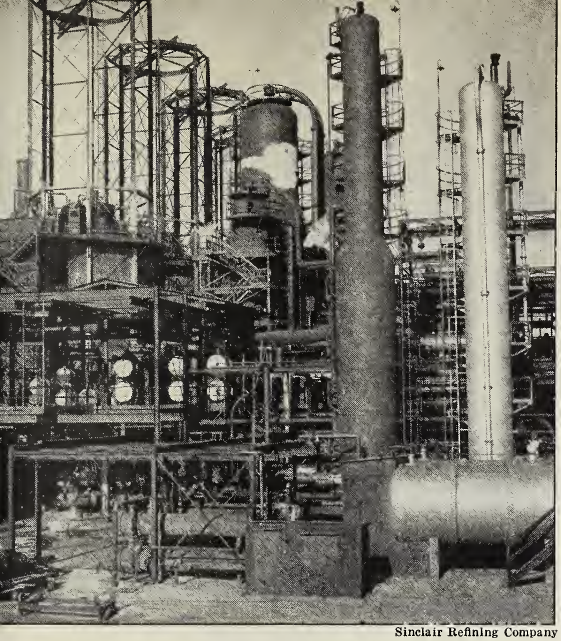
Antiknock gasoline. The knock produced in a motor is due either to a deposit of carbon in the engine or to a too rapid combustion of the gasoline used. If caused by the latter, the knock may be reduced or eliminated by the use of antiknock gasoline. Distilled gas burns faster than cracked gas and is more apt to produce knocking. However, cracked gas may also cause knocking. To overcome knocking, tetraethyl lead ($Pb(C_2H_5)_4$) and ethylene dibromide ($C_2H_4Br_2$) are used. The tetraethyl lead slows down the burning of the gasoline and eliminates the knock. The ethylene dibromide is added to react with the freed lead to form volatile compounds, which are removed from the engine; in this way it prevents the "shorting" of spark plugs. Gasoline containing tetraethyl lead is called ethyl or leaded gas. Since tetraethyl lead is poisonous, most states require that gasoline containing this compound be so labeled and contain a dye.

The octane number indicates the degree of the antiknock quality of a gasoline. The number is



American Petroleum Institute

Rock formations where drilling for oil is carried on. Petroleum will rise to the surface wherever the oil sands are not covered (A). Where, as more frequently happens, oil is trapped by an impervious layer of rock (B) or by natural rock "faults" (C), the oil may be secured only by drilling wells. As will be seen from (D), not all wells within an oil field will succeed in tapping an oil pool



Sinclair Refining Company

A combination crude still and cracking still in an oil refinery

obtained by comparing the antiknock quality of a certain brand of gasoline with the antiknock quality of a mixture of normal heptane and isooctane. The higher the number, the less will be the tendency of the gasoline to cause knocking.

Grades of gasoline. The three common grades of gasoline are premium, regular, and third grade.

Premium gasoline has an octane rating of from 72 to 82. It usually contains tetraethyl lead. It will not remove carbon; no gasoline will remove carbon. It sells at a price of two or three cents per gallon more than regular gasoline.

Regular gasoline has an octane rating of from 67 to 72. It often contains tetraethyl lead and will perform satisfactorily in more cars than third-grade gasoline. Its price is from one to three cents per gallon higher than that of third-grade gasoline.

Third-grade gasoline will serve well in low-compression engines. Its octane rating is between 50 and 67. Although premium and regular gasolines are made for high-compression engines, many motorists find that their high-compression engines will run satisfactorily with third-grade gasoline.

It is advisable for each motorist to experiment with these grades of gasoline and to select the one that meets best the requirements of his motor.

Lubricating oils. One of the important requirements of any internal-combustion engine is that it be properly lubricated. It is essential, then, that motorists know how to select oil and use it properly. There are so many different brands of oil on the market that it is impossible to make any hard-and-fast rules to govern selection. The wise motorist will experiment with different oils until he finds one that meets the requirements of his motor.

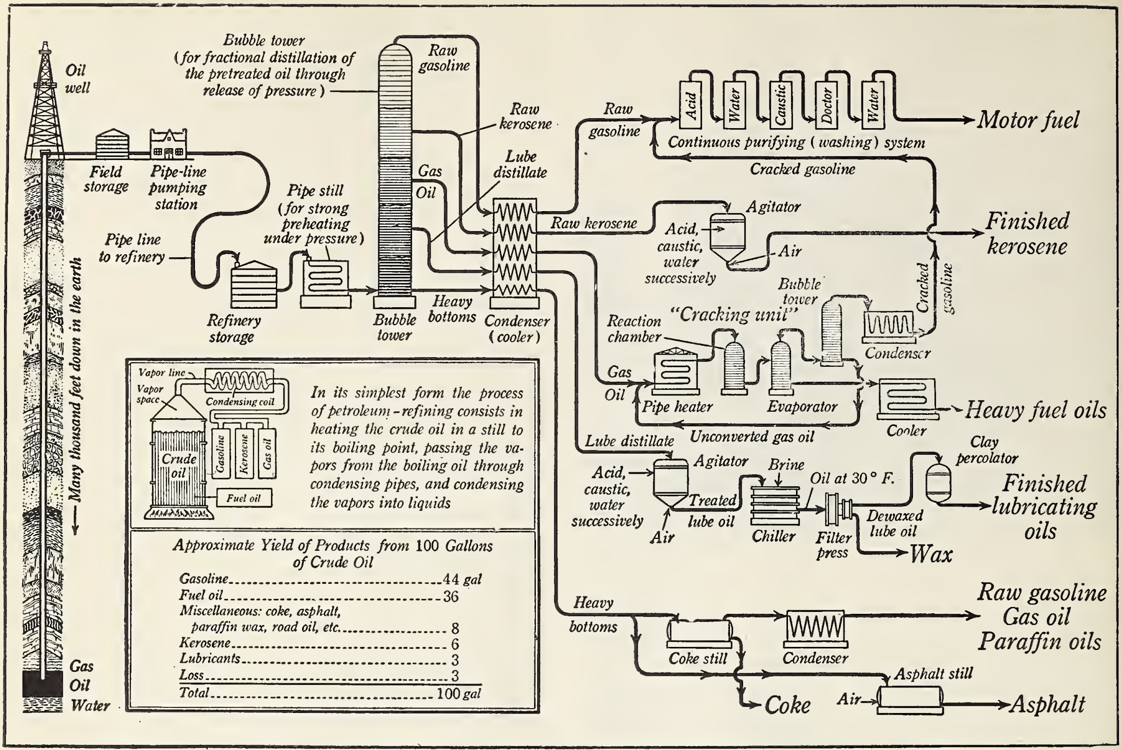
Oils are sold according to S.A.E. (Society of Automotive Engineers) numbers, which are viscosity numbers, such as 10, 20, and 30. Viscosity refers to the resistance to flow, or thickness, of the oil; and the larger the number, the greater the viscosity. There is a general belief that light oil will not lubricate as well as heavy oil. This is not true. Most cars are being made to use light oil, and the only good excuse for using a heavy oil is that a motor has become so worn that it will not hold a light oil.

Oils should not be judged on the basis of price. Many oils selling at 15 cents a quart are as good as some oils selling at 35 cents a quart. It is possible to save a considerable amount of money by buying oil in five-gallon cans. Oil which costs $1.40 per gallon when bought by the quart can be purchased for as little as 60 cents a gallon in five-gallon lots.

Reclaimed oil is oil which has been refined after it has been used and discarded. It sells for from 10 cents to 15 cents a quart. If the refining has been carefully done, this oil will serve as well as unused lubricating oil.

Intake of a bromine-extraction plant. The sea rolls in to give up its bromine content. This chemical is used in making antiknock compounds for the gasoline that we burn in our cars

Dow Chemical Company



In its simplest form the process of petroleum-refining consists in heating the crude oil in a still to its boiling point, passing the vapors from the boiling oil through condensing pipes, and condensing the vapors into liquids

Approximate Yield of Products from 100 Gallons of Crude Oil

Gasoline	44 *gal*
Fuel oil	36
Miscellaneous: coke, asphalt, paraffin wax, road oil, etc.	8
Kerosene	6
Lubricants	3
Loss	3
Total	100 *gal*

American Petroleum Institute

A flow chart tracing crude oil from well to finished product

EXERCISES

1. What are the theories as to the origin of petroleum?

2. Describe the chemical nature of petroleum.

3. How are the useful products obtained from petroleum? Describe the process fully.

4. Chemically, what is gasoline?

5. Describe the process of cracking petroleum.

6. How is polymerized gasoline made?

7. How is the gasoline that is sold today made?

8. How is the antiknock gasoline that is sold today made?

9. How does antiknock gasoline keep a motor from knocking?

10. What is an octane number? What does such a number signify?

11. Name and describe the three grades of gasoline.

12. What do the viscosity numbers of lubricating oils mean? What use should be made of these numbers?

13. How should oil be bought?

14. What is reclaimed oil?

The Explosive Industry

Explosives in the work of the world. Almost the only time that the ordinary person becomes conscious of the use of explosives is when he is stopped by a man with a red flag because of blasting ahead. Thousands of tons of explosives are used annually in building new roads or widening old ones. Modern highways and railroads now run through great cuts or through tunnels in mountains. Great canals have been dug to save thousands of miles of travel by water. Explosives are used to clear land of stumps. Oil wells are "shot" to bring in gushers. Wild animals are killed by bullets propelled by explosives.

Unfortunately, man has not always used his knowledge of explosives for useful pursuits. He has perfected explosives to be used in making warfare more deadly. Bombs, torpedoes, and other explosive projectiles are employed with devastating results. Man, then, can use in a destructive way his

Lone Star Cement Corporation

Tunnels are blasted through mountains with explosives. Many transcontinental trains now cross the continental divide in the Rockies through the 6.2-mile tunnel under James Peak

scientific knowledge of how to release the power stored up as chemical energy in many compounds and mixtures, or he can use it in making the world a more pleasant place in which to live.

How do explosives work? There are two general types of explosives: those which burn and those which disintegrate as a whole. Both types owe their explosive force to the vast amount of gas which is suddenly formed when they are set off. Some are mixtures, and others are pure compounds. The burning type is composed of (1) mixtures of substances which burn rapidly to form gases and (2) oxidizing agents, principally nitrates, which bring about the rapid oxidation of the combustible substances. Black gunpowder is an example of this type. Some explosives, such as nitroglycerin ($C_3H_5(NO_3)_3$), are very unstable compounds which detonate, or explode, with terrific violence. The molecules of these solid or liquid compounds literally blow up into gaseous compounds and elements which expand thousands of times in volume because of the great heat which is generated by the reaction. If the explosive is embedded in rock or enclosed in a shell, the thousands of pounds per square inch of pressure which is generated shatters the rock or sends the projectile at a tremendous speed to a great distance.

Most explosives are unstable compounds because of the element nitrogen, which they contain. Nitrogen is a rather inert element. It is hard to get it to unite with other elements; and when it does, the compounds are very unstable. The nitrate radical (NO_3) and the nitro radical (NO_2) are found in most explosives. When placed with other substances which will take the oxygen readily, the nitrogen gives up the oxygen to these substances and becomes free nitrogen gas. The volume increases greatly if the oxygen unites with other substances which also form gases. A great deal of heat is generated by the rapid oxidation, and this causes the gases to increase further in volume.

Black gunpowder was invented by the Chinese thousands of years ago but was used only in fireworks. It was not used in cannons until the thir-

E. I. Du Pont de Nemours & Co.

In some quarries so-called dynamite shots are used to bring down the stone. Tunnels are driven into the side of a hill and dynamite is placed in the tunnels. This picture shows such a dynamite shot as the dynamite explodes

teenth century and was not used for blasting until the seventeenth century. It is composed of approximately 75 per cent potassium nitrate (KNO_3), 15 per cent carbon, and 10 per cent sulfur. It is a mixture and burns rapidly. The equation for this reaction is as follows:

$$2\,KNO_3 + S + 3\,C \longrightarrow K_2S\downarrow + N_2\uparrow + 3\,CO_2$$

A good deal of smoke is generated, owing to the K_2S and to the formation of unburned carbon.

Smokeless powders have been developed to eliminate the smoke caused by the burning of black gunpowder. Smokeless powder is made by dissolving guncotton in a solvent to form a gelatinous mass. This is molded into grains or small perforated rods and allowed to dry.

Guncotton is made by treating cotton (cellulose) with nitric acid. The cellulose hexanitrate which is formed has the formula $C_{12}H_{14}(NO_3)_6O_4$ and is used in making the common smokeless shotgun shells.

Nitroglycerin is prepared by treating glycerin ($C_3H_5(OH)_3$) with nitric acid (HNO_3) and sulfuric acid (H_2SO_4). The sulfuric acid does not enter into the reaction but acts as a dehydrating agent. The reaction is as follows:

$$C_3H_5(OH)_3 + 3\,HNO_3 \longrightarrow C_3H_5(NO_3)_3 + 3\,H_2O$$

Nitroglycerin is an oily liquid and explodes easily when jarred or suddenly struck. It is used in "shooting" oil wells and in making dynamite.

Dynamite is used extensively in the blasting of rock. It contains nitroglycerin which has been mixed with porous sawdust and a special ground clay. Ammonium nitrate is often added to the mixture. A rather severe jar or shock is needed to set off dynamite. Detonator caps are used for this purpose. These caps contain a substance which will explode suddenly when struck sharply or when heated. Mercury fulminate ($Hg(CNO)_2$) or potassium chlorate ($KClO_3$) is often used in such detonators as dynamite caps and shotgun-shell caps.

Trinitrotoluene ($C_6H_2(CH_3)(NO_2)_3$), or TNT, is made by treating toluene (C_7H_8) with nitric acid. TNT is used in many high-explosive shells for warfare. It can be handled safely, as a strong detonator is required to explode it. It is sometimes mixed with guncotton in large shells.

EXERCISES

1. Discuss the importance of explosives in the modern world.

2. Name and describe the action of the two general types of explosives.

3. What are the chemical and physical characteristics of explosives?

4. How is black gunpowder made? Describe its action, using an equation to illustrate.

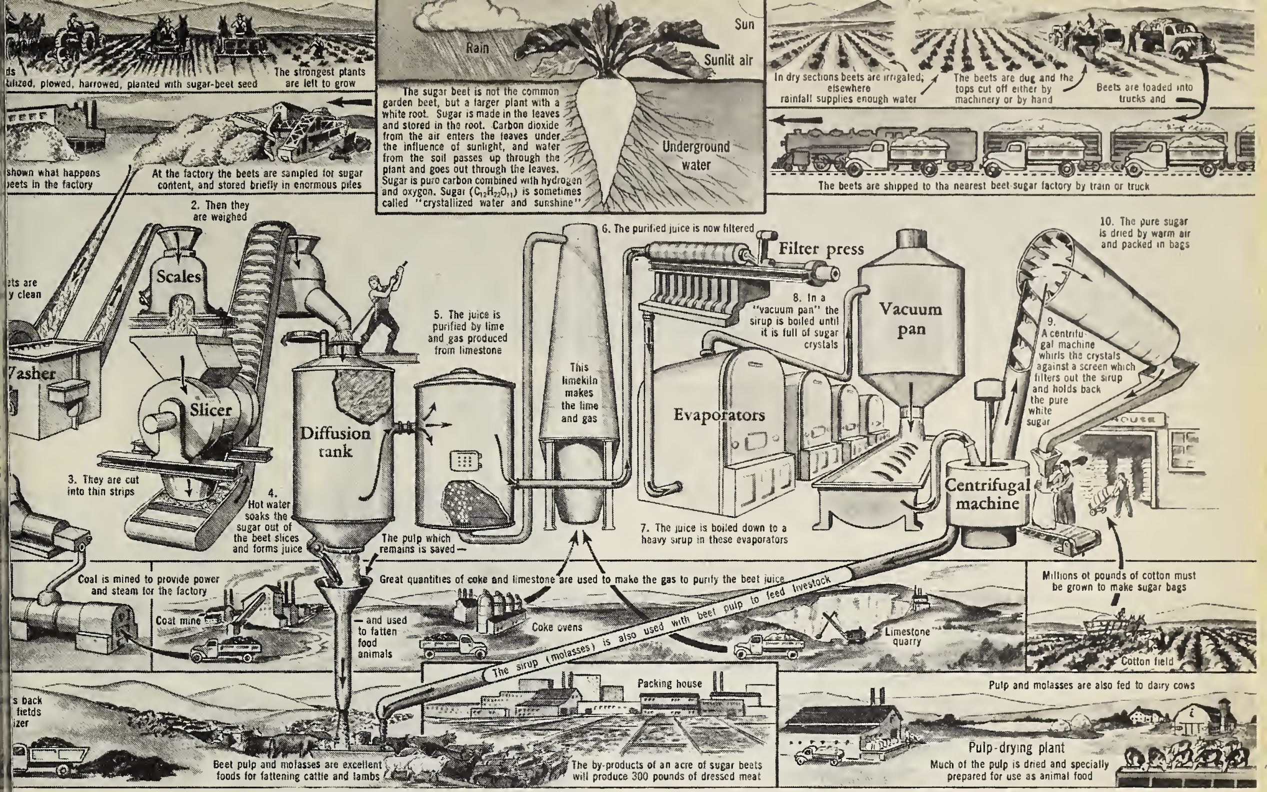
5. How are smokeless powders made?

6. Describe the manufacture of nitroglycerin. Write the equation for the reaction.

7. What is dynamite? TNT?

Some "safe" explosives will not explode even when hit repeatedly with a sledge hammer. Such explosives require a powerful detonating cap to cause them to explode

E. I. Du Pont de Nemours & Co.


ds
tilized, plowed, harrowed, planted with sugar-beet seed
The strongest plants are left to grow
Rain
Sun
Sunlit air
The sugar beet is not the common garden beet, but a larger plant with a white root. Sugar is made in the leaves and stored in the root. Carbon dioxide from the air enters the leaves under the influence of sunlight, and water from the soil passes up through the plant and goes out through the leaves. Sugar is pure carbon combined with hydrogen and oxygen. Sugar ($C_{12}H_{22}O_{11}$) is sometimes called "crystallized water and sunshine"
Underground water
In dry sections beets are irrigated; elsewhere rainfall supplies enough water
The beets are dug and the tops cut off either by machinery or by hand
Beets are loaded into trucks and
The beets are shipped to tha nearest beet-sugar factory by train or truck
shown what happens
beets in the factory
At the factory the beets are sampled for sugar content, and stored briefly in enormous piles
2. Then they are weighed
ets are
y clean
Scales
asher
Slicer
3. They are cut into thin strips
4. Hot water soaks the sugar out of the beet slices and forms juice
Diffusion tank
The pulp which remains is saved—
— and used to fatten food animals
5. The juice is purified by lime and gas produced from limestone
This limekiln makes the lime and gas
6. The purified juice is now filtered
Filter press
8. In a "vacuum pan" the sirup is boiled until it is full of sugar crystals
Vacuum pan
Evaporators
7. The juice is boiled down to a heavy sirup in these evaporators
10. The pure sugar is dried by warm air and packed in bags
9. A centrifugal machine whirls the crystals against a screen which filters out the sirup and holds back the pure white sugar
Centrifugal machine
Coal is mined to provide power and steam for the factory
Coal mine
Great quantities of coke and limestone are used to make the gas to purify the beet juice
Coke ovens
Limestone quarry
The sirup (molasses) is also used with beet pulp to feed livestock
Millions of pounds of cotton must be grown to make sugar bags
Cotton field
s back
fields
izer
Beet pulp and molasses are excellent foods for fattening cattle and lambs
Packing house
The by-products of an acre of sugar beets will produce 300 pounds of dressed meat
Pulp and molasses are also fed to dairy cows
Pulp-drying plant
Much of the pulp is dried and specially prepared for use as animal food

United States Beet Sugar Association

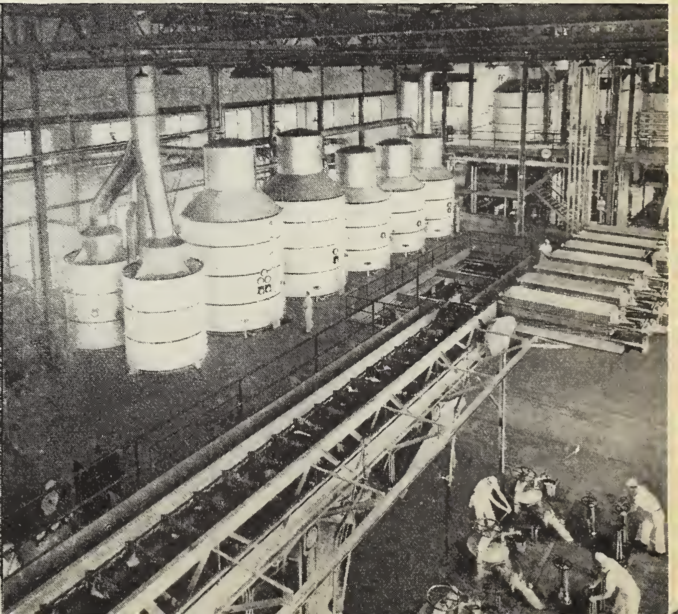
The story of beet sugar

After having been harvested, sugar beets are stored in huge piles outside the factories until needed

United States Beet Sugar Association

Interior view of a modern beet-sugar factory. Sliced sugar beets are being carried by a conveyer belt to the diffusion tanks, shown in the lower right-hand corner of the picture. The vacuum pans are located on the left side of the refinery, and a row of filter presses may be seen in the right center

United States Beet Sugar Association



American Sugar Refining Company

Sugar cane being carried to a refinery from a Cuban plantation

American Sugar Refining Company

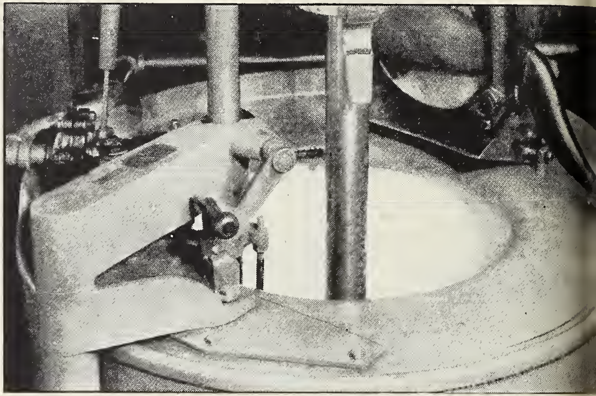
Sugar cane being shredded as it passes by chute conveyers to the crushers, which remove the juice from the shredded cane

The Sugar Industry

Source of sugar. The sugar used on our tables is the carbohydrate sucrose ($C_{12}H_{22}O_{11}$). It is found in the juices of many plants. It is found most concentrated in the juice of the sugar beet and sugar cane and in the sap of the maple tree. Table sugar is manufactured from the juice of the sugar beet or sugar cane. Both these have the same chemical formula and, when refined to the pure state, are identical. It would be difficult for a chemist to tell from which source a sample of table sugar was derived. Some housewives believe that cane sugar or a certain brand of sugar is sweeter than beet sugar or another brand of sugar. This is an erroneous belief. It is also impossible to tell beet sugar from cane sugar by the size of the crystal because this is controlled during the process of manufacture. Either kind of sugar may be made in fine or in coarse crystals. Beet sugar and cane sugar are equally good for making jelly or jam.

The manufacture of beet sugar. The beets are washed thoroughly and cut into long V-shaped shreds called cossettes. The cossettes are placed in large cylindrical boilers, where they are heated with water to leach out the sugar and juice. The juice is drained off and made alkaline with lime ($Ca(OH)_2$). This causes many of the organic salts to precipitate out. The solution is then filtered. The excess $Ca(OH)_2$ is removed by carbonation. This is done by treating the solution with carbon dioxide. The precipitated $CaCO_3$ is removed by filtration. Sulfur dioxide is added to bleach the juice.

The water is then removed by evaporating the juice in vacuum pans. The vacuum lowers the boiling point and thus prevents scorching, or burning, of the sugar. When the liquor reaches a certain concentration, the operator places some mother crystals in the vat, and crystallization takes place. The molasses, or thick juice, is extracted by placing the moist crystalline mass in a centrifugal machine which contains a fine-mesh wire screen basket. The molasses is thrown out through the holes in the screen by centrifugal force. The crystals of sugar are washed by playing a fine stream of water on them as they rotate at a high rate of speed. Then the moist sugar is dried in large rotating screen



American Sugar Refining Company

From the vacuum pans the crystallized mixture goes to a centrifugal machine consisting of a large cylindrical basket with fine-screen sides. The basket is spun at a high speed, throwing off the adhering sirup and retaining the sugar crystals inside the screen. In this picture the granulated sugar may be seen on the sides of the whirling basket cylinders through which warm air is blown. The screened sugar is then ready to be sacked for the market.

The beet pulp may be dried and mixed with the molasses to be sold as food for cattle. Sometimes the wet pulp is sold for this purpose, but it imparts a bitter taste to cow's milk.

The manufacture of cane sugar. Sugar cane is crushed by running the stalks of the plant between several rollers. The organic impurities are removed by precipitating them out with milk of lime ($Ca(OH)_2$). The juice is filtered, and the excess $Ca(OH)_2$ is precipitated out with CO_2:

$$Ca(OH)_2 + CO_2 \longrightarrow CaCO_3\downarrow + HOH$$

The juice is again filtered and run through animal charcoal, or bone black, to remove any color. It is then evaporated under vacuum, crystallized, and separated from the molasses in centrifugal machines in a manner similar to that used in making beet sugar. After the sugar is dried and screened, it is ready to be sacked for shipment. The molasses is used in making food for cattle, sold as sirup for table use, or fermented to make alcohol or rum. Brown sugar is cane sugar which still contains some of the molasses.

EXERCISES

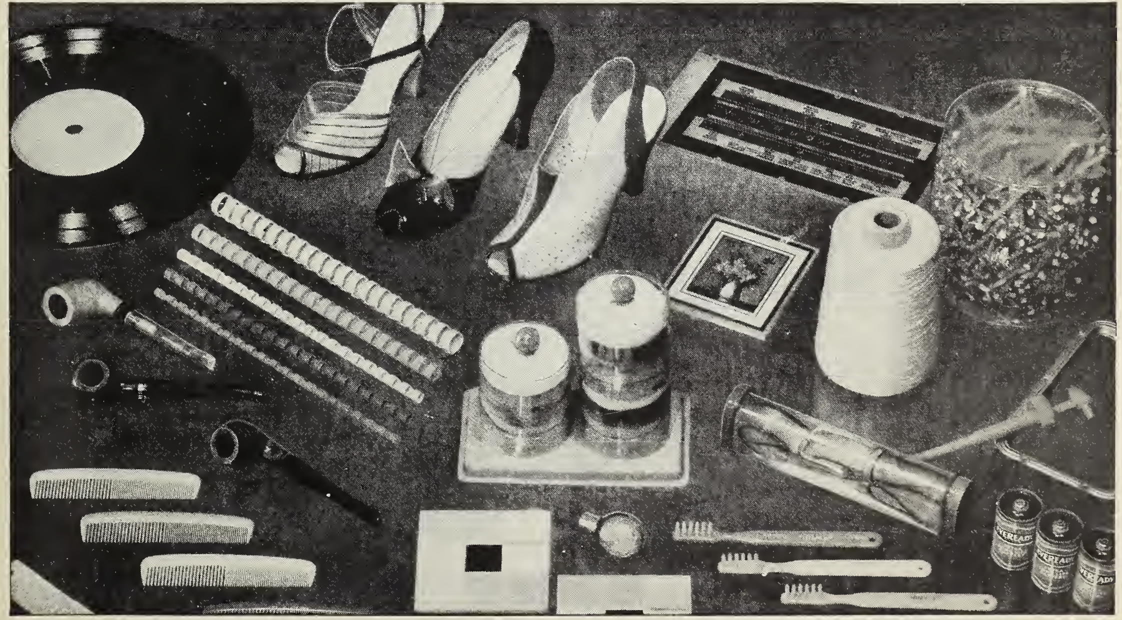
1. What are the sources of common sugar?
2. Is there a difference between beet sugar and cane sugar? Discuss.
3. Describe fully the process of manufacturing beet sugar.
4. How is cane sugar made?

The Plastics Industry

Chemists have brought a new industry into being. Within a period of ten years a new industry has been born. This industry has given new life and glamour to many articles which we use every day. The fountain pen, the dresser set, the salt-and-pepper set, and the boudoir lamp are much more attractive today than they were a few years ago. These articles and many others that help to make our homes and our personal accessories more attractive are products of the plastics industry.

The objects shown in this picture were made from synthetic plastics

Carbide and Carbon Chemicals Corporation



What is a plastic? Plastics are substances which can be shaped or molded. Such plastics as amber, tar, pitch, and resins have been known for many years. However, only in recent years have synthetic plastics been developed.

The nature and use of synthetic plastics. There are many different kinds of synthetic plastics. The most common types are cellulose acetate, pyroxylin, phenolformaldehyde, vinyl, and methacrylate.

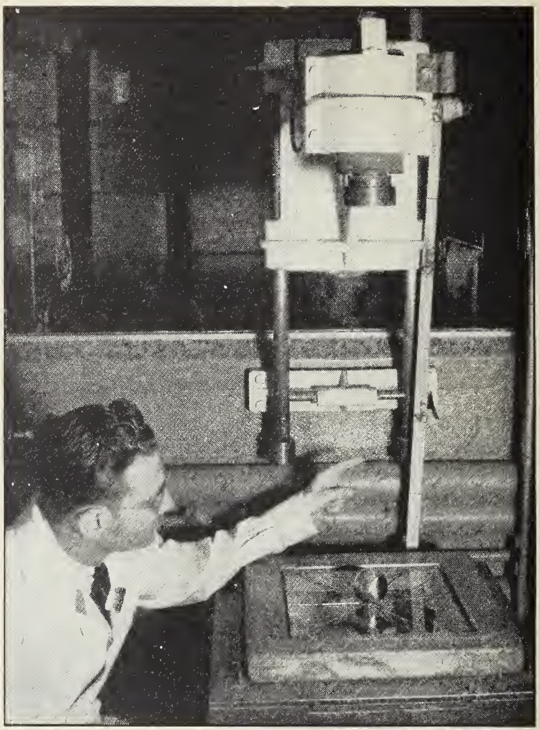
Cellulose acetate plastic is made by subjecting cotton linters to the action of glacial acetic acid ($HC_2H_3O_2$) and acetic anhydride. This type of plastic takes a variety of colors because it is transparent and contains no natural color. It is inflammable but burns slowly. Cellulose acetate plastic is strong, but its use is somewhat limited because it is expensive. It is used to make many articles, one of which is safety motion-picture film.

Pyroxylin, or nitrocellulose plastic, is made by treating cotton linters with nitric and sulfuric acid. Too much nitration of the cotton produces guncotton, an explosive which contains about 13 per cent nitrogen. A plastic is formed when the nitration is stopped at the point where the product contains from 10 per cent to 12 per cent nitrogen. Pyroxylin is a white solid; but when it is dissolved in an organic solvent and the mixture is allowed to dry, a transparent film is obtained.

Pyroxylin makes a durable and tough plastic. Because of these properties it has found wide use whenever a thin coating of strong, wear-resistant material is needed. It is used for serving trays, shoe heels, and clock cases. It will take almost any color. The one great disadvantage of pyroxylin is its high inflammability.

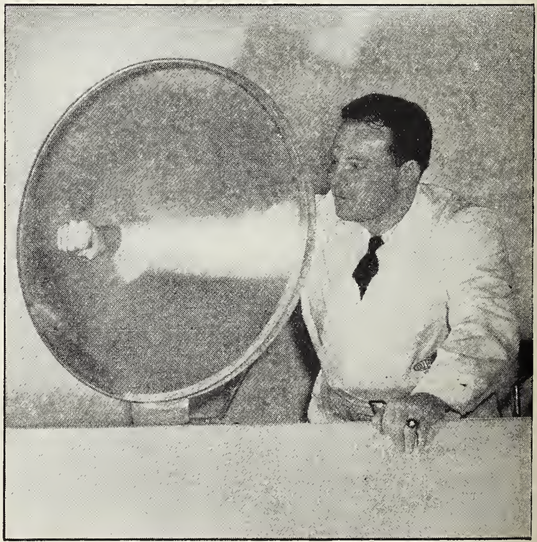
Phenolformaldehyde plastic is produced when phenol (carbolic acid, C_6H_5OH) is heated with formaldehyde ($HCHO$) in the presence of a catalyst. It colors well and is water-repellent and acid-resistant. It has a wide variety of uses, such as for table tops, gearshift balls, and clothing accessories. This plastic is sold under a number of trade names, the most common of which is "Bakelite."

Vinyl plastic is produced when vinyl chloride ($CH_2{:}CHCl$) and vinyl acetate ($CH_3 \cdot CO_2 \cdot CH{:}CH_2$) are polymerized together. Vinyl plastics are hard, strong, water-resistant, and noninflammable. They are used to make transcription records and bottle



Ford Motor Company

This engineer is testing the effectiveness of shatterproof glass to be used in automobile windows



E. I. Du Pont de Nemours & Co.

Chemists have perfected a type of plastic glass which will eliminate the danger of shattered glass in certain uses caps and to line beverage and food containers. This material is also used in making transparent belts, suspenders, shoes, and other wearing apparel.

Methacrylate plastics, sometimes called acrylic resinoids, are made from cotton, coal, camphor, crude oil, and acids. Plastics of this type are unusually valuable because they transmit light as well as glass does. Over one half of the ultraviolet rays of sunlight will pass through this plastic material. Because of these properties it is used for windows when a relatively unbreakable material is desired and for prisms and lenses. Its trade name is "Lucite."

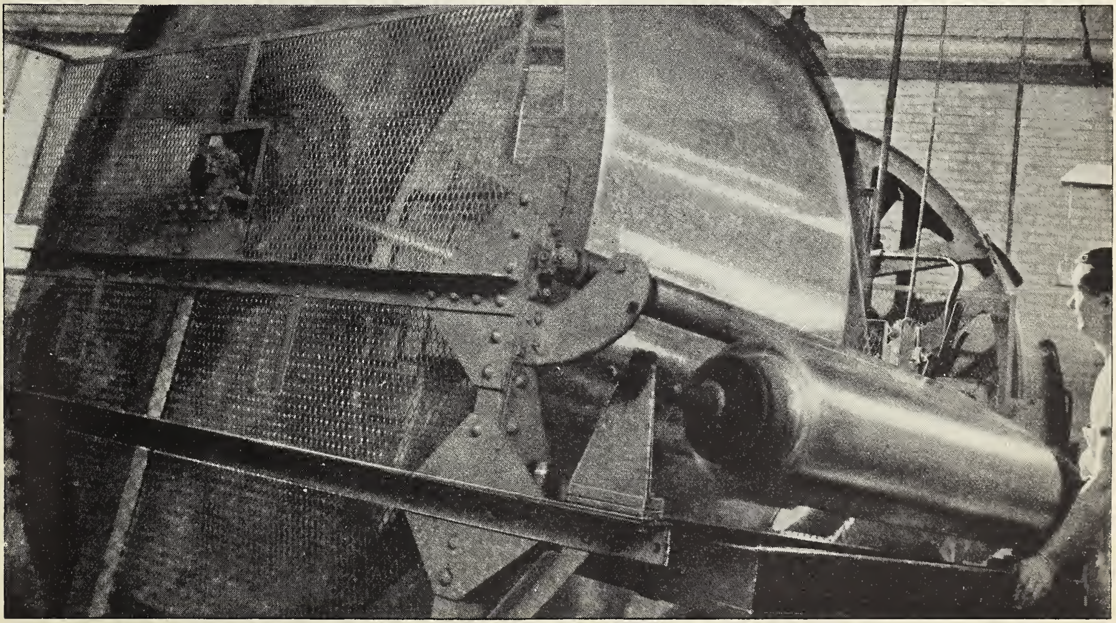
"Cellophane." The use of "Cellophane" has grown by leaps and bounds. Fifteen years ago its price, of over $2.50 a pound, was prohibitive. Today, with the price less than 35 cents a pound, it is widely used.

"Cellophane" is made by a process similar to the viscose method of making rayon. Viscose is forced through a narrow metal slit into an acid bath. This causes the liquid to solidify into a thin, transparent sheet. It may be waterproofed with transparent lacquer, and it is manufactured in a wide range of vivid colors.

"Cellophane" has hundreds of uses, and new ones are being discovered every day. Perhaps it is most widely used in the packaging of foods, clothing, and other articles. The advantages of this method of packaging are

1. The articles are protected from contamination by bacteria which may be in the air or on the hands of people handling them.
2. The customer can see what he buys.
3. The articles are protected from dirt, dust, moisture, and other substances in the air.
4. The flavor or odor of food, tobacco, cosmetics, etc. is preserved.
5. The product is made more attractive.

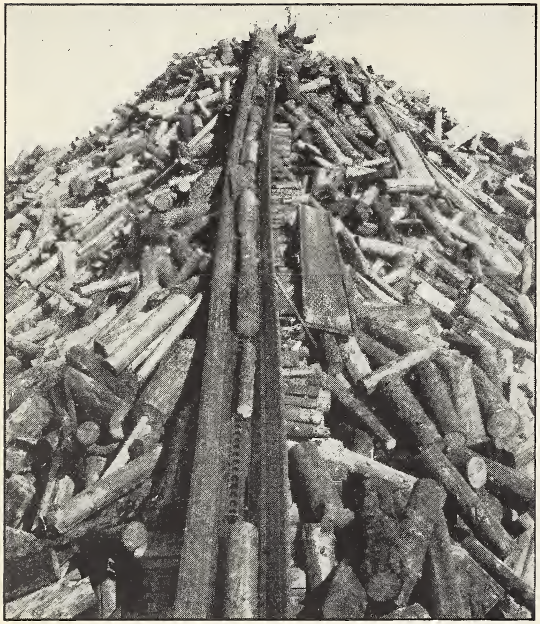
"Cellophane" is becoming useful in the manufacture of articles of clothing. Raincoats and hats made of this material are gaining in popularity. Articles of clothing are frequently stored in bags made of "Cellophane." It is also used, among other things, for electrical insulation, curtains, and coverings for valuable works of art and documents of historical importance.



E. I. Du Pont de Nemours & Co.

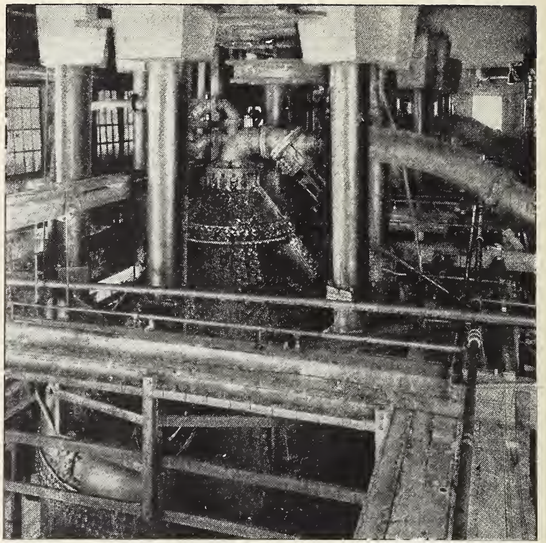
Rolls of "Cellophane" (cellulose film) are run off onto large cylindrical drums. The "Cellophane" is then cut to specific lengths on order

The Manufacture of Paper



S. D. Warren Company

A conveyer piling logs in the woodyard of a paper mill. Coniferous woods (spruce and other evergreens) are converted into sulfite pulp. Wood from deciduous trees (such as poplar) are converted into soda pulp. These logs will next be cut into chips by high-speed cutting knives

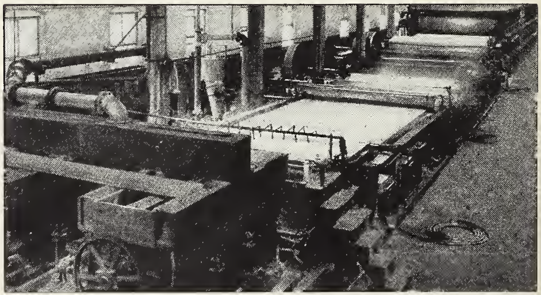


S. D. Warren Company

Wood chips which are free of bark and defective spots are cooked in chemicals to remove gums and resins. Coniferous woods are cooked in a sulfurous acid solution and become sulfite pulp. Poplar and similar woods, from deciduous trees, are cooked in a sodium hydroxide solution and become soda pulp. The cooking device is called a digester. The digester shown here extends from the first floor of the building to the fourth floor

S. D. Warren Company

Soda pulp that has been washed and bleached



S. D. Warren Company

A papermaking machine viewed from the "wet end." Wood pulp is fed from the reservoir, shown in the center of the picture, where the steps are. The pulp passes to a moving screen. As the screen moves forward, it is shaken sideways, so that the pulp fibers are shaken together. Water drains through the screen by suction. At the far end of the screen the wet paper is transferred to "felts," which carry the paper through a series of presses that remove surplus water. The drying rolls at the far end of the machine are heated by steam. These smooth the paper

The manufacturing of paper. Though paper is not generally considered to be a plastic, yet it is made from many of the same raw materials as the plastics are. Most paper is manufactured from wood pulp; the better quality is made from rags. Most of the wood pulp is obtained from spruce, hemlock, and poplar trees.

The wood is first ground or chipped and then cooked in a solution of calcium bisulfite ($Ca(HSO_3)_2$) to remove the rosin and minerals. The remaining pure cellulose is then washed and bleached. The plastic mass is next sized by adding such substances as casein, sodium silicate, starch, and rosin. The sizing helps to close the pores and gives body to the paper. At this point, if coloring is desired, a pigment is added. The mixture is then passed through heated rollers which are set to produce the desired thickness. Then the paper is dried in a drying room.

The making of finer paper from rags is in many ways identical with the making of wood-pulp paper. However, there are a few differences. Great care is taken in cleaning and washing the rags to remove all impurities. There is another variation in the finishing of the paper. In this operation it is sized by being dipped into a glue or gelatin solution. The sized paper is then ironed to produce the desired finish.

EXERCISES

1. How old is the plastics industry?
2. What effect has this industry had upon our lives?
3. What is a plastic?
4. Describe the methods of making the following plastics: cellulose acetate, pyroxylin, phenolformaldehyde, vinyl, and methacrylate.
5. Discuss the use of each type of plastic listed under "The Plastics Industry."
6. How is "Cellophane" made?
7. What uses are made of "Cellophane"?
8. What are the advantages of using "Cellophane" for packaging?
9. Describe the method of manufacturing paper.

The Electrochemical Industry

The relationship between chemistry and electricity. Chemistry and electricity are very closely related in that chemicals may be used to produce electricity, and electricity may be used to carry on certain chemical reactions and processes. The production of electricity in storage batteries and dry cells is the direct result of chemicals and chemical reactions. Electroplating requires electricity, which causes a chemical reaction in the plating bath. This reaction results in the depositing of a metal on the article which is being plated.

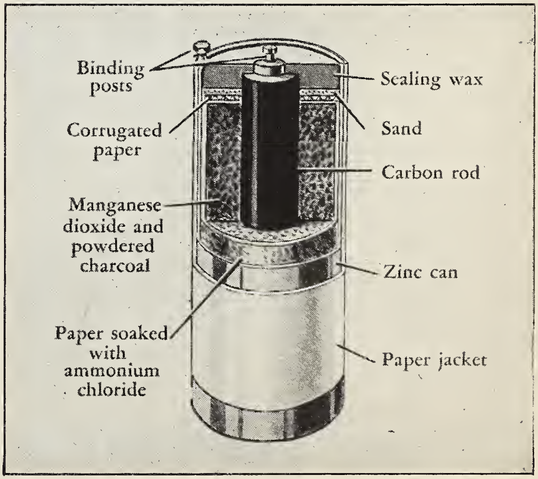
The electroplating industry is a very extensive one. This statement is verified when we consider the many articles in use every day which are silver-plated, gold-plated, copper-plated, and chromium-plated.

The process of electroplating has already been adequately explained. In this discussion, then, we may turn our attention to the dry cell and the storage battery.

The dry cell. The dry cell is a very good source of electricity if only a small amount of current is needed for a short period of time. If it is used continuously, the cell soon wears out. Millions of dry cells are produced every year, and they are used to supply electricity for doorbells, radios, flashlights, and telephones.

The dry cell has a zinc can, which acts as the negative pole of the cell. Within the can is a moist paste of ammonium chloride, zinc chloride, manga-

This cross-sectional view of a dry cell shows its principal parts. When a wire is run from the positive terminal post to the negative terminal post, what causes an electric current to flow through the wire?


Binding posts
Scaling wax
Corrugated paper
Sand
Carbon rod
Manganese dioxide and powdered charcoal
Zinc can
Paper soaked with ammonium chloride
Paper jacket

nese dioxide, and carbon particles. The positive pole, a carbon rod, is suspended in the center of the paste. The can is sealed at the top with a layer of pitch, which retards the evaporation of the water. Actually a dry cell is not dry.

Chemical action. When the positive and negative poles of the cell are connected with a wire, the zinc atoms lose electrons and become zinc ions (Zn^{++}). The released electrons move from the zinc can through the wire to the carbon rod. The ammonium chloride has ionized to form $(NH_4)^+$ and Cl^- ions. The $(NH_4)^+$ ions take the electrons lost by the zinc to form neutral ammonium radicals (NH_4), which in turn form ammonia gas and hydrogen:

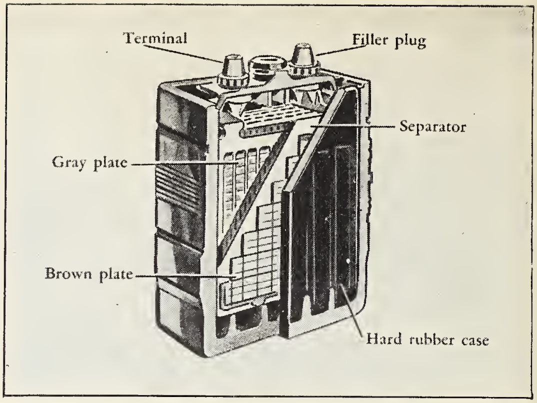
$$2(NH_4) \longrightarrow 2\,NH_3\uparrow + H_2\uparrow$$

Both ammonia gas and hydrogen are released at the carbon pole. The chloride ion (Cl^-) is attracted to the zinc pole, where it reacts with the zinc ions (Zn^{++}). Thus the current from the dry cell is a flow of electrons from the zinc to the carbon pole.

The collection of hydrogen around the carbon pole tends to stop the flow of electrons. This is known as polarization. If the cell is not used continuously, the manganese dioxide will serve well to oxidize the hydrogen, causing the formation of water. If the cell is used continuously, the MnO_2 will be unable to oxidize all the hydrogen, and the electricity produced will gradually diminish.

Selection of dry cells. Dry cells are reasonably priced and can be used in a wide variety of places where a power line or a storage battery would be impractical. In purchasing a dry cell, there are two factors to be considered: (1) the age of the cell and (2) the current produced. As a dry cell ages, it tends to lose strength, even if it is not actually in use. When one buys a dry cell, the retailer should be willing to test it with an ammeter to see that the current produced is equal to the claims made by the manufacturer.

The storage battery. A storage battery does not store electricity but converts chemical energy into electrical energy. This transformation is similar to that which takes place in the dry cell. Both processes involve ionization and the flow of electrons, although different chemicals and materials are used.



A cross section of a storage battery, showing the plates and the insulators between the plates

The ordinary automobile storage battery is made up of three cells which are incased in a hard-rubber box. Each cell consists of a series of plates immersed in a sulfuric acid bath. The three cells may contain eleven or more plates each. The negative plates of a battery are lead plates with pockets of pure spongy lead, and the positive plates are dark-brown lead peroxide (PbO_2) on a lead support. The number of negative plates is always greater by one than the number of positive plates. All the negative plates are connected together and joined to a pole at the top of the battery. The same is true of the positive plates. The plates are placed very close together and are separated by insulators. Evaporation is retarded by sealing the battery with a coat of pitch.

Chemical action. When the battery is being used, the negative lead plates are oxidized, which results in the formation of positive lead ions (Pb^{++}). This causes electrons to be released, which flow through the wires, producing the current. At the same time, the positive PbO_2 plates are being reduced; that is, lead ions with a valence of 4^+ are reduced to lead ions with a valence of 2^+ (Pb^{++++} to Pb^{++}). The sulfate ion (SO_4^{--}) of the sulfuric acid reacts with the lead ions of both plates to produce lead sulfate, which adheres to the plates. The equation describing the reaction which takes place during charging and discharging is

$$\underset{+\text{ plate}\ -\text{ plate}}{Pb + PbO_2} + 2\,H_2SO_4 \underset{\xleftarrow[\text{charging}]{}}{\overset{\xrightarrow{\text{discharging}}}{\rightleftarrows}} \overset{+\text{ plate}}{PbSO_4} + \overset{-\text{ plate}}{PbSO_4} + 2\,H_2O$$

You should notice that when the battery is used, or discharged, sulfuric acid is being used, and water is formed. Since water is lighter in weight than sulfuric acid, the charge of the battery is found by measuring the specific gravity of the electrolyte with a hydrometer. A battery which has just been charged should have a specific gravity of from 1.275 to 1.300. When the specific gravity falls below 1.150, the battery is generally discharged.

How to care for and purchase a storage battery. Evaporation, especially during warm weather, removes water from a storage battery. It is essential that this water be replaced. The water added to the battery should be free from chemicals composed of metals. The water used should be distilled in nonmetallic stills and serviced from nonmetallic containers. Failure to add water causes more damage to batteries than any other one thing. The battery should be tested periodically with a hydrometer to see that it is well charged. The top, including the poles, should be kept free of dirt and corrosion. If the battery is not in use, it should be recharged every thirty to forty-five days.

In purchasing a battery, there are at least three important factors to be considered: (1) the number of plates, (2) the ampere-hour rating, and (3) the guarantee. Of two batteries equal in quality, it is generally true that the one with more plates is the more powerful and serviceable. Compare the prices of batteries in relation to the number of plates before you buy. All batteries are rated according to ampere-hours. A 90-ampere-hour battery will deliver 90 amperes of current for 1 hour or 1 ampere for 90 hours. A battery having a rating below 90 ampere-hours is usually not desirable. Many companies are now offering "ironclad" guarantees on batteries. It is now possible to get a reasonably priced battery with a 36 months' guarantee. If the battery wears out in 24 months, you are given one-third credit on a new one.

EXERCISES

1. How are chemistry and electricity related?
2. How does the dry cell produce electricity? Describe fully.
3. Describe fully how through chemical action the storage battery produces electricity.
4. What does the specific gravity of a storage battery indicate?
5. How should a storage battery be cared for?

PROBLEMS FOR FURTHER STUDY

1. How are automobile tires made?
2. How is "Celluloid" made?
3. How is used oil refined?
4. How is corn sugar made?
5. What are some of the newer uses being made of alloys?
6. How does an oil-filter work?

UNIT EXERCISES

A. On a separate sheet of paper write the word *true* for those statements which are true, and the word *false* for those which are false. Do nothing for those about which you are doubtful. Rewrite the false statements so that they are true.

1. Modern industry could not exist without iron and steel.
2. Iron-ore deposits are not very abundant in nature.
3. Steel is the final product of the blast furnace.
4. Cast iron is an impure form of iron.
5. Because of its brittleness, cast iron is useless.
6. Steel is tempered by subjecting it to intense pressure.
7. Wrought iron is used wherever a malleable type of iron is needed.
8. An alloy is a compound of two metallic elements.
9. By varying the percentage and kinds of elements it is possible to make an alloy with almost any desired property.
10. By knowing the properties of the elements which make up an alloy it is possible to predict accurately the properties of the alloy.
11. The cord of rubber tires may be made stronger by dipping it in latex.
12. Natural rubber is superior to synthetic rubber because it deteriorates less in oil and in air.
13. Petroleum probably was formed from decayed animal and vegetable matter.
14. Gasoline is a mixture of several compounds of the methane series.
15. Cracked gasoline is superior to gasoline made from the straight-run distillation of crude oil.
16. The lower the octane rating of gasoline, the less will be the knock that is produced in the motor by the gasoline.
17. There is really no difference between premium, regular, and third-grade qualities of gasoline.

18. A lubricating oil with an S.A.E number of 30 is a better lubricant than one with an S.A.E. number of 10.

19. The quality of a lubricating oil is dependent on its price.

20. Lubricating oil which has been refined after it has been used and discarded should never be used in the motor of an automobile.

21. $C_3H_5(OH)_3 + 3\,HNO_3 \longrightarrow C_3H_5(NO_3)_3 + 3\,H_2O$. This is the equation for the preparation of trinitrotoluene.

22. All explosives must be set off with a detonator cap.

23. Beet sugar is not as good for making jelly as cane sugar.

24. Pure cane sugar is sweeter than pure maple sugar.

25. The manufacture of beet and cane sugar involves (*a*) leaching out the sugar and juices, (*b*) removing impurities, and (*c*) crystallizing the sugar from the purified liquor.

26. Amber, tar, pitch, and resins are natural plastics.

27. Synthetic plastics were manufactured over a hundred years ago.

28. "Bakelite" is made from carbolic acid and formaldehyde.

29. "Cellophane" has made living more sanitary.

30. If the ingredients of the dry cell were dry, no electricity would be produced.

31. The electricity in a dry cell is produced through the ionization of the salts present in the cell.

32. Both plates of a charged storage battery are pure lead.

33. It is not necessary to use distilled water in a storage battery.

B. On a separate sheet of paper write whatever is necessary to complete each statement correctly. Do not write in this book.

1. Steel is an alloy of iron and --(?)--.

2. The principal ores of iron are --(?)-- and --(?)--.

3. The reduction of the oxide ore of iron in a blast furnace is made possible through the use of hot air and --(?)--.

4. The two processes used to make most steel are --(?)-- and --(?)--.

5. In a ferrous alloy one of the elements is --(?)--.

6. In order that rubber may have strength, durability, and stretching quality, it must go through a process called --(?)--.

7. Commercially, synthetic rubber is made from --(?)--.

8. Petroleum is a mixture of --(?)-- of the methane series.

9. The useful products of petroleum are obtained through a process known as --(?)--.

10. The heavier, slower-burning compounds of the methane series may be decomposed into gasoline by a process known as --(?)--.

11. Explosives owe their force to the vast amount of --(?)-- which is suddenly formed when they are set off.

12. Black gunpowder is composed of potassium nitrate and the elements --(?)-- and --(?)--.

13. Smokeless powders are made by dissolving --(?)-- in a solvent.

14. "Cellophane" is made by a process similar to the --(?)-- method of making --(?)--.

15. The best quality of paper is made from --(?)--, and the cheaper quality from --(?)--.

16. In purchasing a dry cell two important factors should be considered, --(?)-- and --(?)--.

17. The electrolyte in a storage battery is --(?)--.

18. Two important factors to be checked in purchasing a storage battery are --(?)-- and --(?)--.

C. In Group I are listed some common alloys. In Group II may be found the use or uses of each of these alloys. On a separate sheet of paper write together the number of each alloy and the number of its use or uses.

Group I. (1) Stainless steel; (2) Babbitt metal; (3) bronze; (4) "Duralumin"; (5) monel metal; (6) pewter; (7) Wood's metal.

Group II. (1) Sink boards and plumbing fixtures; (2) dishes and ornaments; (3) automatic fire sprinklers; (4) cutlery; (5) soldering; (6) airplane framework; (7) type for printing; (8) machine bearings; (9) statuary.

REFERENCES FOR FURTHER READING

Beery, Pauline G. *Stuff: The Story of Materials in the Service of Man.* D. Appleton-Century Company, Inc., New York, 1930.

Borth, Christy. *Pioneers of Plenty.* The Bobbs-Merrill Company, New York, 1939.

Howe, H. E. *Chemistry in Industry,* Vols. I and II. The Chemical Foundation, Inc., New York, 1926.

Mausperger, Dale E., and Pepper, Carson W. *Plastics, Problems, and Processes.* International Textbook Company, Scranton, Pennsylvania, 1938.

Morrison, A. Cressy. *Man in a Chemical World.* Charles Scribner's Sons, New York, 1937.

Reich, Edward, and Siegler, John C. *Consumer Goods.* American Book Company, New York, 1937.

The Chemistry of Warfare

The importance of chemistry in modern warfare is recognized by almost everyone. The radio, newspapers, magazines, and movies are daily calling to our attention the many ways in which chemistry is helping us to defend our country and vanquish our foes. We read vivid descriptions and see actual pictures of the destruction caused by explosive and incendiary bombs, both made through a knowledge of chemistry. We hear and read stories of the poisonous gases, made by chemists, which were used in the first World War. Some of our citizens are already learning how to use chemical gas masks in anticipation of attacks during war. We learn that chemists are working night and day to produce new and more destructive explosives, new alloys, better gasoline, and the like. We know that chemists are untiringly experimenting to produce substitutes for commodities which cannot be imported during wartime. Thus chemists are improving synthetic rubber, are working on new ways to reclaim tin, and are producing substitutes for silk, the supply of which is gradually diminishing.

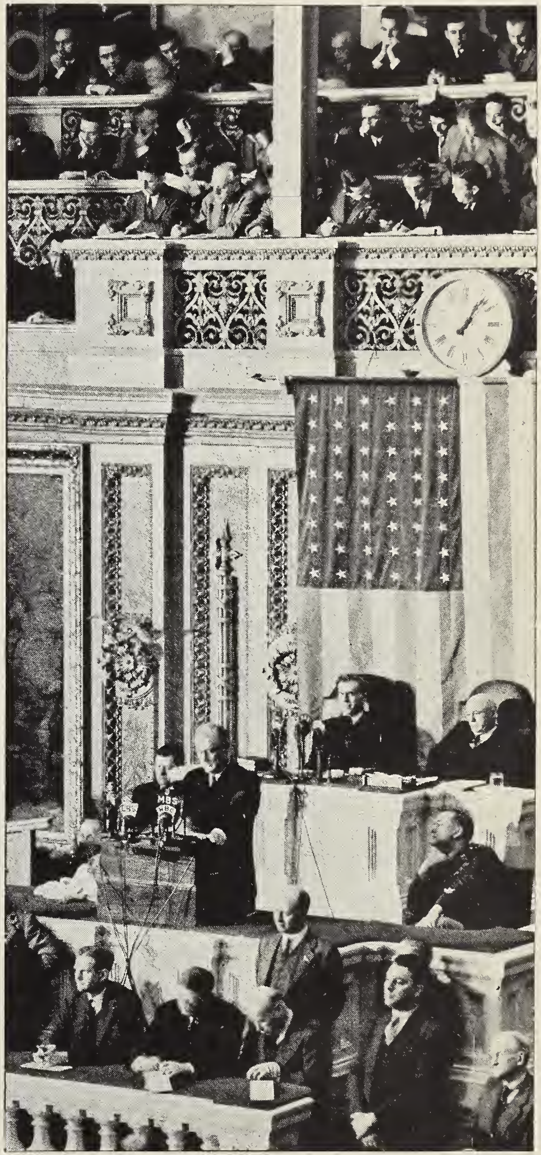
The relationship between chemistry and warfare should be well understood by those who expect to interpret present-day living. This unit will help you to gain that understanding.

PURPOSES TO BE ACHIEVED

1. To gain an understanding of the part that chemistry plays in modern warfare.
2. To become aware of the necessity for diverting materials of peace into materials of war.
3. To learn about some of the precautions and protective measures necessary for personal and community health and safety in time of war.
4. To help everyone to realize his responsibility in the national emergency.

PROBLEMS TO BE SOLVED

1. Why are bombs, torpedoes, and shells so destructive?



Life magazine

President Franklin D. Roosevelt asks Congress for billions to provide the nation with the materials of war

2. What should you know about the poisonous gases used in modern warfare?

3. What are some other important materials used in warfare?

4. Why is it necessary to ration commodities in time of war?

Problem 1. Why are bombs, torpedoes, and shells so destructive?

Explosive devices used in modern warfare. Many kinds and types of explosive bombs, shells, mines, and torpedoes are used in modern warfare. For example, there are three general types of explosive bombs or shells: (1) armor-piercing, (2) demolition, and (3) fragmentation. The armor-piercing bomb or shell has a case strong enough to penetrate several inches of steel before it explodes. The demolition bomb or shell is constructed to burst at the time of contact with the objective and therefore requires a much thinner casing. The fragmentary bomb, or shrapnel, destroys and kills by throwing pieces of its metal case and its contents in all directions when it explodes. The explosive material in these bombs and shells is usually TNT; there is evidence that more powerful, secret explosives are sometimes used.

There are four general methods by which explosive missiles are projected: (1) bombs released from airplanes are carried to their objective by the force of gravity; (2) torpedoes released from a submarine, ship, or airplane are self-propelling by means of an electric motor or some other device; (3) projectiles fired from guns are directed to the objective by the propelling force of explosives; (4) grenades and other small bombs may be thrown by hand. In addition, mines and delayed-action bombs may be placed in strategic places so that they explode after an interval or when an enemy ship or tank comes in contact with them.

High-explosive bombs act in four ways. High-explosive bombs are known to be much more effective in destroying life and property than any other type of explosive missile. The damaging power of this kind of bomb is due to four facts: First, a bomb weighing from 100 to 2000 pounds, in striking the earth or a building, is tremendously de-

These United States bombers are dropping 100-pound bombs on a practice field to develop accuracy

Keystone View Co.

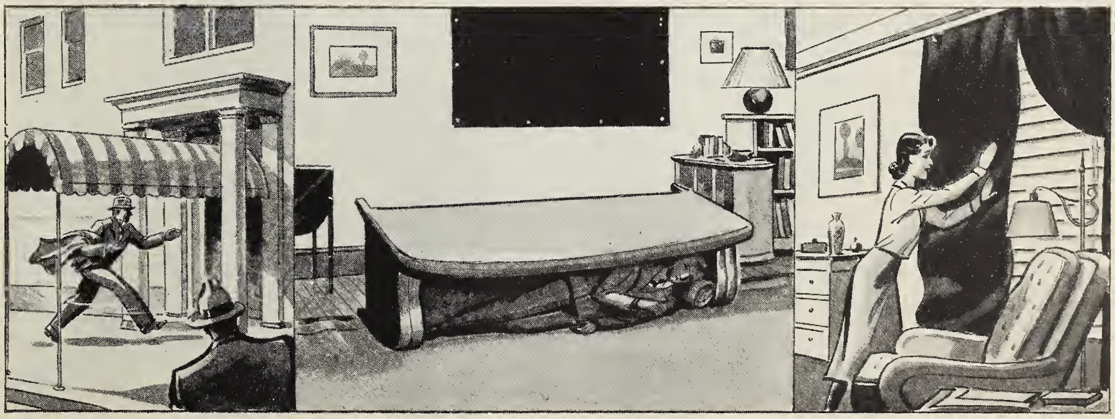
structive. If dropped from an altitude of 20,000 feet, the impact of a 100-pound bomb will be equal to that of a 135,000-pound object dropped a distance of 10 feet. This energy alone is sufficient to do a great amount of damage to buildings. Second, when the bomb explodes at the moment of contact or very soon thereafter, it bursts into thousands of fragments, which are projected in all directions. Each fragment of metal has more energy than a high-powered-rifle bullet and, in the case of a 100-pound bomb, will kill people and damage property within a radius of from 60 to 75 yards from the point of explosion. Third, the outward force of the very rapidly expanding gases from the explosive in the bomb follows the flying fragments. This blast of air is destructive for a distance of from 25 to 35 yards. Fourth, when the blast of expanding air rushes out from the point of the explosion, there is a destructive force in the opposite direction. This force is due to the air which rushes into the vacuum created at the point of the explosion. It is sufficient to pull down the walls of buildings. It is also possible, if the bomb explodes at the surface of the earth or in the earth, that there will be violent earth tremors which may be strong enough to shake down buildings.

What to do in case of an air raid. The United States Office of Civilian Defense has issued the following instructions for civilians when an air-raid signal is sounded:[1]

1. If away from home, seek the nearest shelter. Get off the street.
2. If you are driving, first park your car at the curb; be sure all the lights are turned off.
3. If you are at home, send the others to the refuge room. This should be a comfortable place with as little window exposure as possible, equipped with drinking water, things to read, toilet facilities, a flashlight, a portable radio, a sturdy table, and food if you like.
4. Turn off all gas-stove burners but leave the pilot lights, water-heaters, and furnaces alone. Leave electricity and water on. Fill some large containers or a bathtub with water.
5. Check up on black-out arrangements. Don't let a crack of light show to the outside.
6. See that everyone's eyeglasses and dentures are in the refuge room. There should be additional warm garments for everyone, too.
7. Keep out of line of windows. Fragments and glass splinters cause most casualties.
8. If bombs fall near by, get under a heavy table or an overturned davenport.
9. Don't rush out when the "all clear" signal sounds. Maintain the black-out. The raiders may return.
10. Otherwise, keep cool; be sensible and set an example to others.

Incendiary bombs and materials. Incendiary bombs and materials are used in warfare to destroy buildings and other combustible materials by fire. The principal incendiary instruments are bombs, grenades, and flame-throwers. Fires started with these instruments are hard to extinguish.

One of the safest places to be, in the home, during a bombing attack is under a table or davenport. Why?



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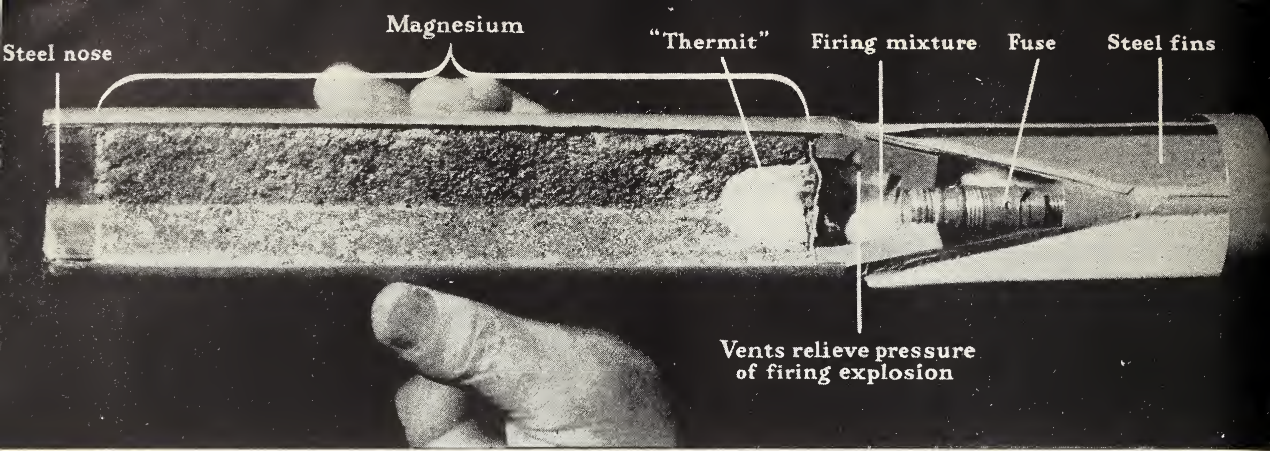
[1] *A Handbook for Auxiliary Firemen.* United States Office of Civilian Defense, Washington, D.C., 1941.



Life magazine

Diagram showing the construction of a magnesium incendiary bomb

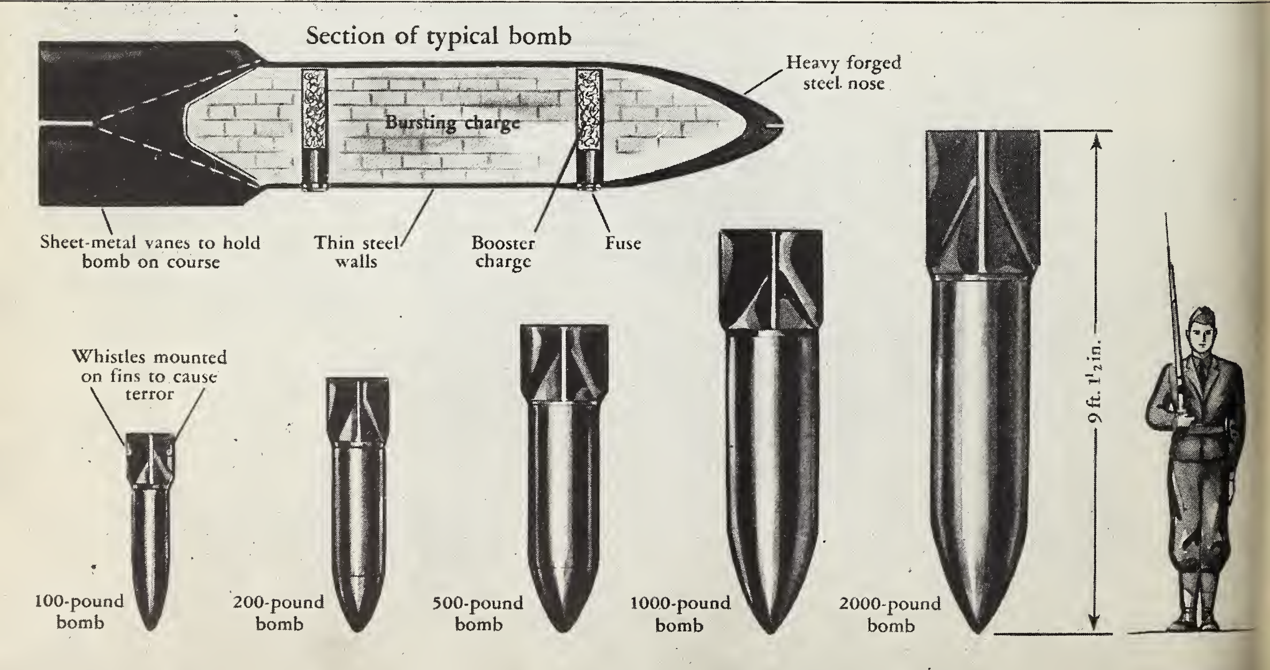
Incendiary bombs are classified under two types, intensive and scatter. There are two kinds of the intensive incendiary bomb. The first contains a mixture of iron oxide and powdered aluminum which is called "Thermit." When this mixture is ignited, the chemical action produces a mass of molten iron which has such an extremely high temperature that it sets fire to any combustible material with which it comes in contact. The equation for this reaction is

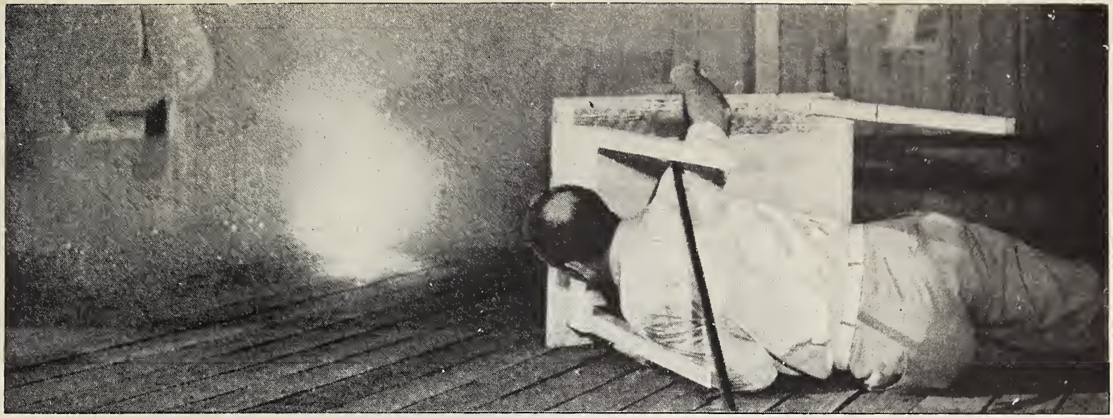
$$Fe_2O_3 + 2\,Al \longrightarrow Al_2O_3 + 2\,Fe$$

This reaction does not depend on oxygen from the air, though the molten iron needs oxygen to continue its incendiary action. This type of bomb weighs $2\frac{1}{2}$ pounds and will burn for from 15 to 20 minutes. The second kind, sometimes called *electron bomb*, has a magnesium-alloy case containing a firing mixture of powdered aluminum, barium nitrate, and black powder. The firing mixture ignites the magnesium-alloy case, which melts and burns at an extremely high temperature. In burning, the alloy requires oxygen from the surrounding air.

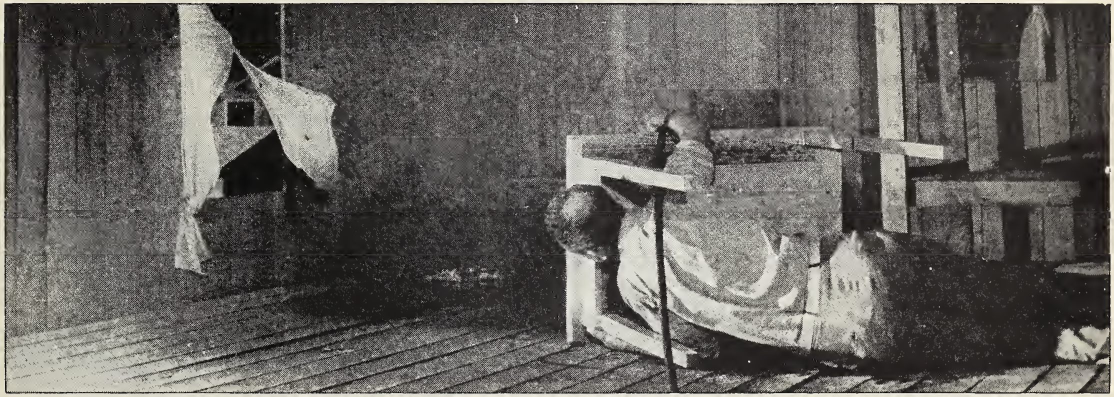
Diagram showing the construction and relative sizes of bombs

Life magazine





No. 1. Attack a magnesium incendiary bomb immediately but protect your eyes and body. For fast results use a jet or stream of water on the bomb. Where violently scattered molten metal and sparks are especially hazardous a spray of water on and around the bomb may be used



No. 2. The bomb has been carefully watched until it has burned out

Life magazine

No. 3. The bomb after it has burned out

These bombs generally contain small amounts of explosives to discourage fire-fighters in their attempt to extinguish the fire. Bombs of this type weigh from 10 to 132 pounds.

The *scatter bomb*, or *grenade*, contains white phosphorus and a small amount of explosive material incased in a thin steel container. The explosive bursts the steel case, and the white phosphorus, which catches fire on contact with the air, is showered over an area of from 50 to 100 square yards. Although the burning phosphorus will not ignite heavy wood construction, it will cause shingles, dry grass, and ripe grain to burn. The greatest danger occurs when the burning phosphorus comes in contact with the human body.

Flame-throwers are devices which throw a stream of heavy oil by means of a compressed gas. A device at the nozzle is used to ignite the stream of oil at the will of the operator. Some flame-throwers are small enough to be carried on a man's back. There are also larger types, which are sometimes used in tanks.

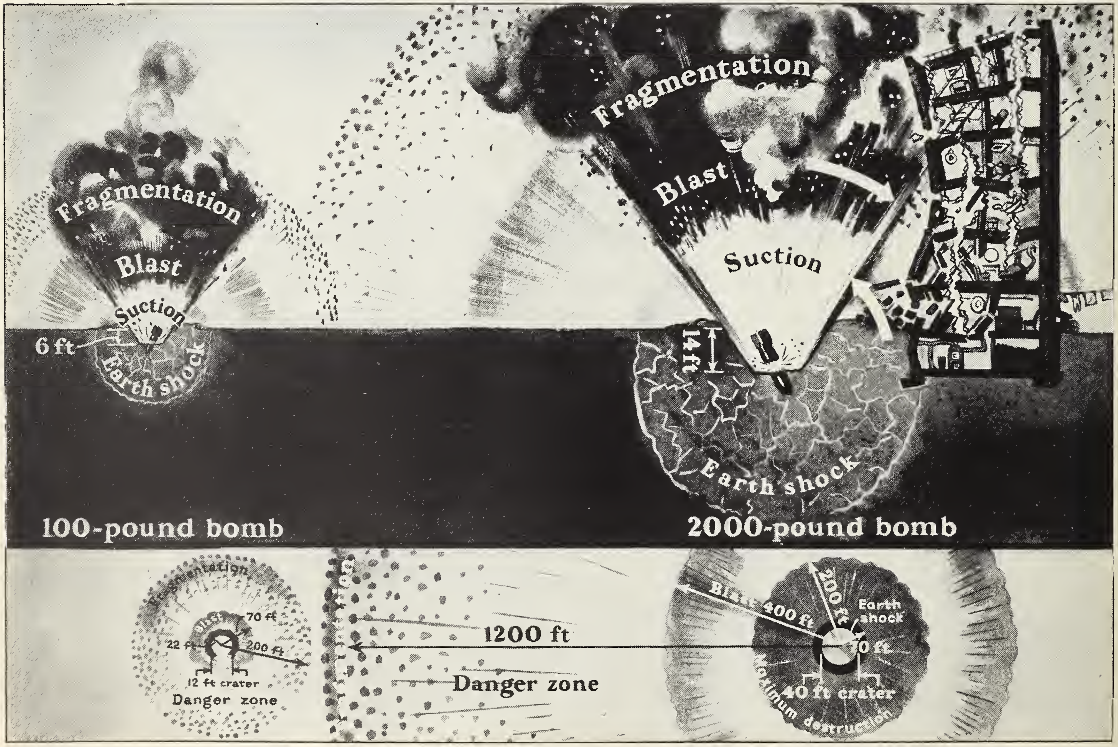
Combating fires caused by incendiary bombs and materials. A fire caused by incendiary bombs is the same as any other fire except that the burning materials—the burning magnesium and phosphorus and the molten iron—are more than ordinarily difficult to extinguish.

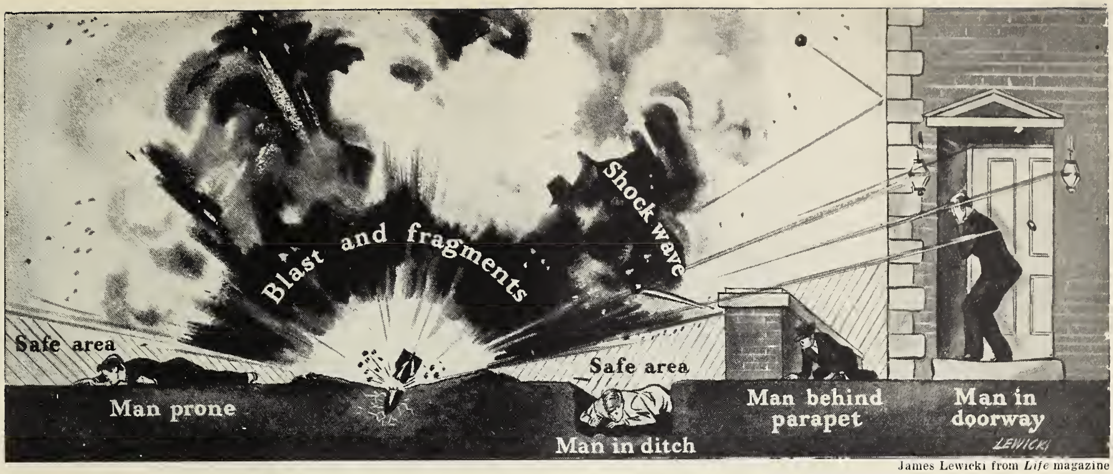
In time of war it is very essential that equipment which is used to extinguish incendiary bombs be kept where it is easily reached so that it may be put to instant use. This equipment may be no more than a garden hose, or it may be a soda-acid extinguisher or a bag of sand.

If an incendiary bomb should fall on a home or similar building, it is quite possible that it would crash through the roof. The person who attempts to extinguish the bomb should shelter himself with

Comparison of the explosive action of a 100-pound bomb and a 2000-pound bomb

James Lewicki from *Life* magazine





James Lewicki from *Life* magazine

This diagram shows the safe areas around an exploding 100-pound bomb

furniture or by standing behind a door and immediately direct upon the burning bomb a strong jet of water from a garden hose or a soda-acid extinguisher. The first reaction after the water hits the bomb will be a burst of white flame and a scattering of molten metal. However, continued application of the strong jet of water will usually extinguish the bomb in a minute or less. The bomb should be quenched thoroughly and any fires started by it should be promptly put out. If an incendiary bomb falls outside a building where it cannot cause a fire, it may be rendered harmless or extinguished by dropping a bag of sand over the burning bomb.

A burning phosphorus bomb, or grenade, should be sprayed with a strong solution of copper sulfate. The water in the solution extinguishes the flame, and the copper sulfate decomposes, releasing free copper, which plates the burning phosphorus. The copper-plated phosphorus should then be collected and burned in a fireproof receptacle.

Oil fires caused by flame-throwers can best be extinguished by a carbon dioxide foam, or "Foamite" extinguisher. If this device is not available, a mixture of sand, calcium and magnesium carbonates, and salt may be used.

In areas where bombing is likely to occur, it is essential that the materials necessary for extinguishing incendiary fires be conveniently located so that they may be available for instant use.

EXERCISES

1. Name and describe the three general types of high-explosive bombs.
2. How are explosive missiles projected?
3. In what ways do high-explosive bombs destroy life and property?
4. What should a person do in case of an air raid?
5. Name the types of incendiary bombs and materials.
6. How are the two types of incendiary bombs constructed, and how do they act to produce fire?
7. How do flame-throwers work?
8. How may incendiary fires caused by the different incendiary materials be extinguished?

Problem 2. What should you know about the poisonous gases used in modern warfare?

The ideal poisonous gas. Most people abhor the use of poisonous gases as instruments of war. The use of these substances was outlawed before the first World War; nevertheless they were widely used by both sides during that war and will probably be used again in the second World War. However, poisonous gases are not as effective in destroying the enemy as many people believe. Though several poisonous substances are known which are deadly if released in confined spaces, it is extremely difficult to produce a sufficient concentration of these substances in open spaces to produce lethal effects. Military experts have long sought the perfect poisonous war gas. Such a gas would be colorless, odorless, very toxic, heavier than air, unaffected by moisture, and quick in action. It would affect not only the respiratory system but the skin and the nerves. It would penetrate clothing and gas masks. In addition to these characteristics, the ideal poisonous gas would be easily manufactured from abundant and cheap raw materials. No such perfect poisonous gas has yet been discovered, or if it has, it has been kept a military secret. Some poisonous gases which most nearly approximate these properties are phosgene, mustard gas, lewisite, and chlorpicrin.

Kinds of war gases. Poisonous gases may be classified under several types: (1) the *lung irritants*, of which phosgene, chlorpicrin, chlorine, and nitric fumes are examples; (2) the *blister gases*, of which mustard gas, lewisite, and ethyldichlorarsine are the best known; (3) the *sneeze gases*, or *sternutators*, of which adamsite, or diphenylaminechlorarsine, and diphenylchlorarsine are most used; (4) the *lachrymators*, or *tear gases*, of which chloracetophenone and brombenzylcyanide are most widely used.

Effects of war gases on the body. The *lung-irritant* war gases usually have a latent, or delayed, effect which comes from one to twelve hours after the time of exposure. The ultimate effect produced on the body from breathing excessive amounts of these gases is a waterlogged condition of the lungs which causes the victim to suffocate, or drown, in his own body fluids. The *blister gases*, or liquid vesicants as they are often called, have a persistent and latent power to produce deep blister-like burns. Even a minute amount in the atmosphere may prove fatal. Exposure for one hour to air which contains one part per million of mustard gas vapor can cause death. A single drop of a vesicant on the skin will produce a large, painful, and dangerous blister. Liquid vesicants, such as mustard gas and lewisite, are absorbed by the skin in much the same way as cloth absorbs ink. Ordinary clothing offers no protection to the body, and specially treated fabrics must be worn by soldiers or decontamination workers if adequate protection is desired. Liquid vesicants burn and blister any and all parts of the body with which the liquid or the gas comes in contact. Thus the lungs may be burned by the gas when it is breathed with air, or the stomach may be burned if water or food contaminated with these agents is taken into the body.

The *sternutators*, or *sneeze gases*, are really finely dispersed solids rather than true gases. Immediately after exposure to these gases the victim is subject to violent sneezing, severe headaches, and nausea. Prolonged exposure sometimes causes mental depression, leading victims to attempt suicide. A person gassed by a sternutator recovers rapidly if he is removed from the atmosphere containing the gas. The *lachrymators*, or *tear gases*, stimulate the tear glands and cause the victim to shed copious tears, thus preventing him from opening his eyes. These gases, though they cause extreme discomfort, are not dangerous, and the victim generally recovers within an hour.

The lung-irritant gases. Phosgene, or carbonyl chloride ($COCl_2$), is a lethal gas made from carbon monoxide and chlorine. It is an effective poison because of its action on moisture. When breathed into the lungs, it reacts with the moisture there to form hydrochloric acid and carbon dioxide. The equation for this reaction is

$$COCl_2 + H_2O \longrightarrow 2\,HCl + CO_2$$

The hydrochloric acid destroys the delicate membranes of the lungs, and the carbon dioxide produces partial suffocation, causing collapse of the victim. Death may result within twenty-four hours. Since phosgene is soluble in water, the gas is not persistent during wet weather. Some measure of protection against this gas is afforded by breathing through a wet cloth. A good gas mask affords complete protection. However, if a sternutator is used coincidently with phosgene, a gas mask may not afford protection. Why not?

Chlorpicrin, or nitrochloroform (CCl_3NO_2), is another of the lung-irritant gases; it has also a lachrymatory effect. It is easily made by the action of nitric acid on picric acid. At ordinary temperatures it is an oily liquid which volatilizes readily. Since its gaseous vapor is 5.6 times as dense as air and is very toxic, this liquid was used extensively as a poisonous gas in the first World War. Though gas masks offer some protection against this gas, they are not wholly effective, because the gas does not combine with any of the ingredients in the gas mask. Chlorpicrin is merely adsorbed by the charcoal within the mask, and continued exposure causes a saturation of the charcoal, which makes it an ineffective filter. Thereafter the gas will pass through the filter, causing the victim to shed tears and vomit. For this reason, this gas is sometimes used to make soldiers more vulnerable to this and to other gases which may be released. Chlorpicrin has a persistence of about three hours when used on open ground.

Liquid vesicants. Mustard gas, or di-chlorethyl sulfide ($S(CH_2CH_2)_2Cl_2$), was the most effective gas used during the first World War. It is an oily, easily volatilized liquid and is practically odorless when present in air in low concentration. It decomposes very slowly and therefore is very persistent. It is easily and widely dispersed and tends to linger in the ground, trenches, or closed places, such as dugouts and bomb shelters, for several days or even months after a gas attack. It attacks the lungs, eyes, and skin of its victim, producing agonizing burns similar to heat burns. Mustard gas burns become infected easily and heal very slowly, thus incapacitating the victim for a long period of time. Although not as deadly as phosgene, mustard gas is the most dreaded of all the war gases. Attacked troops are afforded fairly good protection from this gas by tightly fitting gas masks and gasproof clothing. The masks must not be removed for at least twelve hours after an attack, as the gas is very persistent. Many soldiers have been affected by this gas because they removed their masks too soon. The gasproof clothing must completely cover the wearer's body and be tightened at the wrists and ankles. The greatest care must be used in undressing after exposure to mustard gas, so that soldiers who have been exposed to this gas must have their clothing removed at special decontamination centers.

Lewisite, the compound chlorvinyl-dichlorarsine ($CHClCHAsCl_2$), is made by the interaction of acetylene and arsenic chloride. It is about 20 per cent more toxic than mustard gas. It has little odor, which makes it hard to detect. Lewisite has a multiple action on the body. It is injurious to the lungs, is a liquid vesicant, or blistering agent, and is a general poison—that is, it causes a systemic, or internal, poisoning, owing to the arsenic which it contains. However, it is not as persistent, nor as stable, as mustard gas. It is hazardous to manufacture, explosions occurring very often during the process. This last characteristic has limited its use as a war gas. For protection against lewisite a tight-fitting gas mask and gasproof clothing must be used.

Lachrymators. The two principal tear gases are chloracetophenone ($C_6H_5COCH_2Cl$) and brombenzylcyanide ($C_6H_5CHBrCN$). Chloracetophenone is a solid and is remarkably resistant to heat and moisture. It is used as a lachrymatory agent by dispersing it with an explosive or distilling it into the air with the aid of some burning mixture. For dispersion by burning it is first mixed with three parts of smokeless powder, and the mixture is then burned without explosion. Such burning mixtures may be successfully put into the enemy positions by hand grenades, bombs, or artillery projectiles. When chloracetophenone is in the air in small concentrations, it has an odor similar to that of apple blossoms. Brombenzylcyanide is the most powerful lachrymator that has yet been introduced into warfare. It is a yellowish crystalline solid. It is not very stable, corrodes iron or steel containers, and is sensitive to heat, which properties make it a difficult agent to use in warfare. Brombenzylcyanide has an odor somewhat like that of sour fruit.

Sternutators. The two most frequently used sternutators in warfare are adamsite, or diphenylamine-chlorarsine ($(C_6H_5)_2NHAsCl$), and diphenylchlorarsine ($(C_6H_5)_2AsCl$). These compounds belong to the chemical family known as arsines. They are solids with high melting points and have the power, when dispersed in the form of finely divided dust, of severely irritating the nose and throat passages. Sneezing and vomiting follow exposure. Gas masks, to be effective against these gases, must have a mechanical filter which will remove finely divided solids from the air. Sternutators are dispersed by means of explosive shells.

Gas masks and protective clothing. You have already learned that persons may be protected against poisonous gas by gas masks and protective clothing. Gas masks filter and purify air; they do not supply fresh air. They are designed to fit tightly around the face, so that all air coming into the lungs must first pass through the canister, where the poisonous materials are either absorbed or neutralized. The canister contains activated carbon and granules of specially prepared soda lime. Activated carbon consists of specially prepared highly

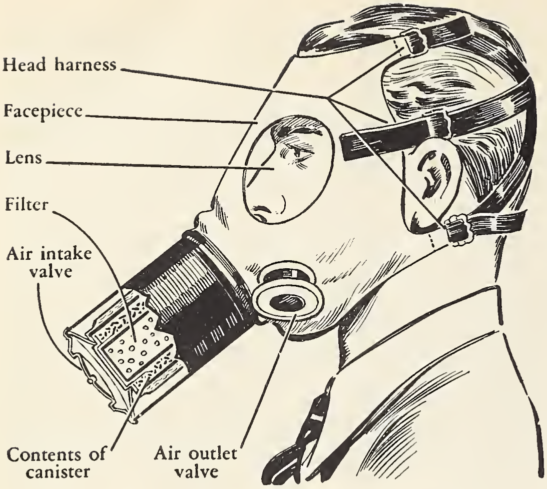


Diagram of a modern noncombatant gas mask

porous, finely divided carbon particles made from coconut shells. In addition, most canisters contain a filter made of cork or some other porous material. The activated charcoal adsorbs the gases in much the same way as a magnet attracts and holds iron particles. The soda lime acts as an additional protective substance because it neutralizes many gases by chemically combining with them. The fibrous filter of the canister must be fine enough to remove the fine particles of sternutators. Thus the gas mask is an efficient device which protects the respiratory tract against all poisonous war gases. However, it should be remembered that continued use of the mask in a poisonous-gas atmosphere produces a saturated condition of the materials in the canister which makes them no longer effective. This condition can generally be detected by a slight odor. When this is noticed, the canister should be replaced by a fresh one. Moreover, gas masks of the type just described do not offer any protection against ammonia fumes or carbon monoxide gas, and they cannot be used in any place where there may be a

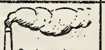
American troops, equipped with gas masks, going through exercises simulating actual battle conditions

Black Star

REFERENCE AND TRAINING CHART

CHEMICAL WARFARE AGENTS

PREPARED BY OFFICE OF CIVILIAN DEFENSE

NAMES AND SYMBOLS	FORM	ODOR	PHYSIOLOGICAL EFFECT	TACTICAL CLASS	PROTECTION	FIRST AID (After removal from gassed area)	PERSISTENCE	FIELD NEUTRALIZATION
MUSTARD $S(CH_2CH_2)_2Cl_2$ DI-CHLORETHYL SULFIDE	LIQUID AND VAPOR	 Garlic, Horseradish, Mustard	Delayed effect. Burns skin or membrane. Inflammation respiratory tract leading to pneumonia. Eye irritation, conjunctivitis.	🚑	😷 🧍	Undress; remove liquid mustard with protective ointment, bleach paste, or kerosene, bathe; wash eyes and nose with soda solution.	One day to one week. Longer if dry or cold.	Cover with unslaked lime and earth. 3% solution of Na_2SO_3.
LEWISITE $CHClCH\text{-}AsCl_2$ CHLORVINYL-DICHLORARSINE	LIQUID AND VAPOR	 Geraniums	Burning or irritation of eyes, nasal passages, respiratory tract, skin. Arsenical poison.	🚑	😷 🧍	Undress; remove liquid lewisite with hydrogen peroxide. lye in glycerine, or kerosene. bathe; wash eyes and nose with soda, Rest—Doctor.	One day to one week. Longer if dry or cold.	Wash down with water. Cover with earth. Alcohol. NaOH spray.
ETHYLDICHLORARSINE $C_2H_5\text{-}AsCl_2$	LIQUID AND VAPOR OR GAS	 Stinging, like pepper in nose	Causes blisters, sores, paralysis of hands, vomiting. Severe on long exposure.	🚑	😷 🧍	Undress; remove liquid with hydrogen peroxide, lye in glycerine, or kerosene: bathe; wash eyes and nose with soda. Rest—Doctor.	One hour.	Cover with earth. caustic.
CHLORINE Cl_2	GAS	Highly pungent	Lung irritant.	🚑	😷	Remove from gassed area. Keep quiet and warm. Coffee as stimulant.	10 minutes.	Alkaline solution.
CHLORPICRIN CCl_3NO_2 NITROCHLOROFORM	GAS	 Flypaper, anise	Causes severe coughing, crying, vomiting.	⛑ 🚑	😷	Wash eyes, keep quiet and warm. Do not use bandages.	Open 6 hours. Woods 12 hours.	Na_2SO_3—Sodium sulfite in alcohol solution.
DIPHOSGENE $ClCOOC\text{-}Cl_3$ TRICHLORMETHYL CHLOROFORMATE	GAS	 Ensilege, Acrid	Causes coughing, breathing hurts, eyes water, toxic.	🚑	😷	Keep quiet and warm. Give coffee as a stimulant.	30 minutes	Alkali.
PHOSGENE $COCl_2$ CARBONYL CHLORIDE	GAS	 Musty hay. Green corn	Irritation of lungs. occasional vomiting. tears in eyes, doped feeling. Occasionally symptoms delayed. Later collapse, heart failure.	🚑	😷	Keep quiet and warm, bed rest. Coffee as a stimulant. Loosen clothing. No alcohol or cigarettes.	10 to 30 minutes.	Alkali.
CHLORACETOPHENONE $C_6H_5CO\text{-}CH_2Cl$	GAS	 Apple blossoms	Makes eyes smart. Shut tightly. Tears flow. Temporary.	⛑	😷	Wash eyes with cold water or boric acid solution. Do not bandage. Face wind. For skin, sodium sulfite solution.	10 minutes.	Strong, hot solution of sodium carbonate.
BROMBENZYLCYANIDE $C_6H_5CH\text{-}BrCN$	GAS	 Sour fruit	Eyes smart, shut, tears flow. Effect lasts some time. Headache.	⛑	😷	Wash eyes with boric acid. Do not bandage.	Several days. (Weeks in winter.)	Alcoholic sodium hydroxide spray.
ADAMSITE $(C_6H_5)_2NHAsCl$ DIPHENYLAMINECHLORARSINE	GAS	 Coal smoke	Causes sneezing, sick depressed feeling, and headache.	⛑	😷	Keep quiet and warm. Loosen clothing. Reassure. Spray nose with neo-synephrin or sniff bleaching powder. Aspirin for headache.	10 minutes.	Bleaching powder solution.
DIPHENYLCHLORARSINE $(C_6H_5)_2\text{-}AsCl$	SMOKE	 Shoe polish	Causes sick feeling and headache.	⛑	😷	Remove to pure air, keep quiet. Sniff chlorine from bleaching powder bottle.	Summer 10 minutes.	Bleaching powder solution.
H C MIXTURE $ZN+C_2Cl_6$	SMOKE	Sharp-Acrid	Harmless.	☁	None needed.	Produces no effect requiring treatment.	While burning.	None needed.
SULFUR TRIOXIDE SO_3+SO_3HCl IN CHLORSULFONIC ACID	SMOKE	 Burning matches	Causes prickling of skin, flow of tears.	☁	😷	Wash with soda solution.	5 to 10 minutes.	Alkaline solution
TITANIUMTETRACHLORIDE $TiCl_4$	SMOKE	Acrid	Harmless.	☁	None needed.	Produces no effect requiring treatment.	10 minutes.	None needed.
WHITE PHOSPHORUS P	SMOKE	 Burning matches	Burning pieces adhere to skin, clothing.	🔥 ⛑ ☁	None needed.	Pack in cloths wet with copper sulfate (blue vitriol) or water or immerse in water. Pick or squeeze out particles. Treat for burn.	10 minutes.	Burns out.
"THERMIT" $2Al+Fe_2O_3$	INCENDIARY	None	5,000 degree heat ignites materials.	🔥	None needed.	Treat for severe burn.	5 minutes.	Quickly cover with earth or sand.

GENERAL INSTRUCTIONS

The importance of proper first aid for gas victims cannot be overemphasized. The following are general rules which apply in all cases:

A. Act promptly and quietly; be calm.

B. Put a gas mask on the patient if gas is still present or, if he has a mask on, check to see that his is properly adjusted. If a mask is not available, wet a handkerchief or other cloth and have him breathe through it.

C. Keep the patient at absolute rest; loosen clothing to facilitate breathing.

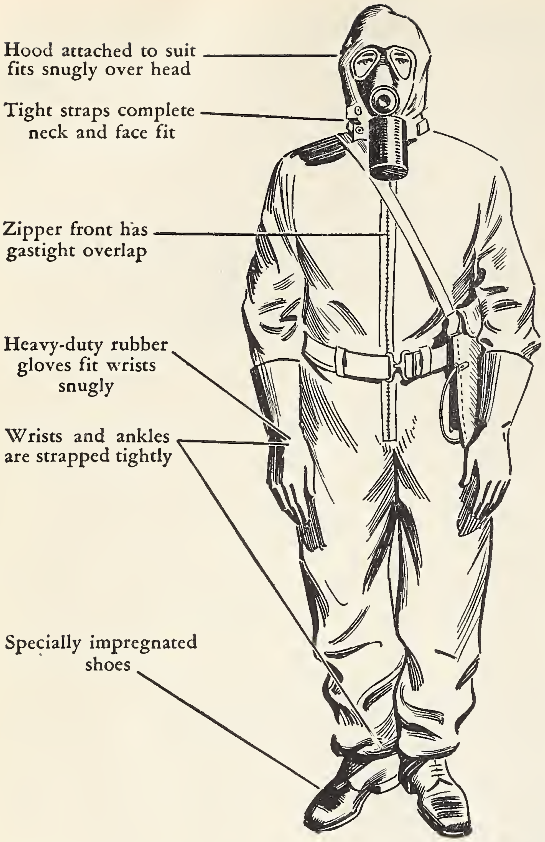
D. Remove the patient to a gasfree place as soon as possible.

E. Summon medical aid promptly; if possible, send the victim to a hospital.

F. Do not permit the patient to smoke, as this causes coughing and, hence, exertion.

KEY

🚑 HOSPITAL CASE
⛑ FIRST-AID TREATMENT
☁ SMOKE
🔥 INCENDIARY
😷 MASK PROTECTION NEEDED
🧍 FULL PROTECTIVE CLOTHING NEEDED


Hood attached to suit fits snugly over head
Tight straps complete neck and face fit
Zipper front has gastight overlap
Heavy-duty rubber gloves fit wrists snugly
Wrists and ankles are strapped tightly
Specially impregnated shoes

Impregnated clothing protects the body from liquid vesicants

lack of sufficient fresh air. Impregnated clothing may be used to protect the body against gases which attack the skin. These garments are made of ordinary clothing materials which are impregnated with chemicals that react with vesicant gases to neutralize them. Such clothing may be worn as any everyday clothing is worn.

The chart on page 521 has been prepared by the United States Office of Civilian Defense.[1] You should study it thoroughly so that you may be able to detect the presence of any poisonous war gas, learn the physiological effects of each gas, and know how to administer first aid to persons who have been gassed.

EXERCISES

1. What properties would an ideal poisonous gas possess?

2. Classify the poisonous war gases according to their effects on the body.

3. What is meant by the term *liquid vesicants*? Give two examples of a liquid vesicant.

4. How does a lung-irritant gas affect the lungs?

5. Explain the effect of liquid vesicants on human tissue.

6. What is meant by the persistence of a war gas?

7. What is a lachrymator? What gases produce a lachrymatory effect?

8. What are sternutators? Describe one such gas and tell of its effect on the human body.

9. When are sternutators and lachrymators used in modern warfare? Why?

10. What is phosgene? Why is it an effective war gas?

11. Describe the use of chlorpicrin as a poisonous war gas.

12. Describe the chemical and physical properties of mustard gas.

13. What is meant by the latent effect of a poisonous gas?

14. How is lewisite made? What are its outstanding characteristics?

15. How do the effects of mustard gas and lewisite differ?

16. List the poisonous gases of war and describe the characteristic odor of each.

17. How does a gas mask protect a person from the effects of poisonous gas?

18. Describe the contents of the canister of a gas mask. Why is each material used?

19. How can you detect the presence of a poisonous gas?

20. How should persons who have undergone exposure to the effects of poisonous gas be treated?

Problem 3. What are some other important materials used in warfare?

Strategic, critical, and essential war materials. The United States War Department made a study of those minerals which are necessary for the defense and safety of our country and classified them as strategic, critical, and essential. Strategic minerals are those of which there is an inadequate domestic supply and which are used in the production of materials related to the promotion of war or are essential for the promotion of the health and safety of the country. Critical minerals are those of which we have an adequate supply to meet our normal needs, but of which during time of war there may be a shortage unless their consumption is controlled and their production is increased. Essential minerals include those which are essential to national defense and of which no shortage in wartime is anticipated. However, new developments during time of war may necessitate reclassification of some of these essential minerals as strategic or critical.

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[1] *A Handbook for Decontamination Squads.* United States Office of Civilian Defense, Washington, D.C., 1941.

The following list was prepared by the War Department in 1939. This list contains only minerals; it does not contain other strategic materials, such as rubber, silk, hemp, and quinine.

Strategic, Critical, and Essential War Materials

Strategic	Critical	Essential
Aluminum	Asbestos	Abrasives
Antimony	Asphalt	Arsenic
Chromium	Cadmium	Chlorine
Manganese	Cryolite	Copper
Mercury	Fluorspar	Helium
Mica	Graphite	Iron and steel
Nickel	Iodine	Lead
Tin	Molybdenum	Magnesium
Tungsten	Platinum	Nitrates
	Titanium	Petroleum
	Vanadium	Phosphates
		Potash
		Sulfur
		Uranium
		Zinc
		Zirconium

Some of the metals in this list which are most important in the prosecution of war will be discussed in detail. A study of them will help you to realize why their use is restricted to military and other essential purposes during time of war.

Aluminum. The most important use of aluminum during war is in the manufacture of airplanes. The importance of this metal was brought forcefully to the attention of the American people shortly before the United States entered the second World War, when they were asked to contribute to the government aluminum utensils and other aluminum articles which were not being used. The entire production of new aluminum was diverted from the manufacture of peacetime materials to the manufacture of war materials. It became impossible for housewives to buy aluminum ware after merchant stocks were depleted. The production of aluminum in existing aluminum plants was greatly increased, and new plants were constructed. Thus, because of the national emergency, the amount of aluminum produced in the United States has been increased enormously.

Antimony. The chief antimony-producing countries are China, Mexico, and Bolivia. The principal ore is stibnite (Sb_2S_3). Three outstanding properties make antimony a valuable metal: (1) it expands slightly when it solidifies, thus making sharp, well-defined castings, as is needed in type metal; (2) it has a low melting point, 630.5° C; (3) it imparts hardness to lead. Antimony is alloyed with lead to make ornamental castings, storage-battery plates, chemical-resistant pipes, bearing metal, and type metal. In war antimony is used to harden the lead from which bullet cores and shrapnel balls are made. The bursting charge of shrapnel shells contains antimony sulfide, which produces a dense white smoke when exploded, thus enabling the location of the burst to be observed. Another important use is in the priming mixture for the detonating caps of rifle and artillery shells.

Mercury. Though the United States produces more mercury than any other country, its consumption of mercury is so great that about one third of the amount needed must be imported. The chief ore of mercury is cinnabar (HgS). The most important uses of mercury are in the manufacturing of drugs, chemicals, dental preparations, and seed disinfectants. The pigment vermilion owes its brilliant red color to mercuric sulfide. The metal is used to form amalgams with other metals. You have probably had a tooth filled with a silver amalgam. It is also used in mercury-vapor lamps, mercury turbines, barometers, and thermometers. The foremost military use of mercury is in the making of fulminate. Mercury fulminate is very explosive and is used as a detonator for other high explosives.

Tin. Unfortunately, the United States produces an insignificant amount of tin, though it is the largest consumer of tin in the world. About 75 per cent of the world's supply comes from the Malay States, Thailand, and the Netherlands Indies. When Japan entered the second World War, this supply was practically cut off. Rationing orders went into effect immediately to conserve our limited supply. The familiar tin cans of oil in filling stations began to disappear, and oil was sold in bulk. Glass containers for foods, instead of cans, began to appear on the grocery shelves. You have already learned how tin protects iron (p. 339). Most of the tin used in this country goes into the making of tin plate. Tin foil is largely tin alloyed with lead. Many useful alloys contain tin, including bearing metals, bronze, and solder.

Magnesium. Very little magnesium has been produced until recently. It is a silvery-white metal and is only about two-thirds as heavy as aluminum. It is alloyed with aluminum in various proportions to form the "Dowmetals." These alloys contain from 85 to 95 per cent magnesium. They are strong, weather-resistant, and extremely light. These properties make them valuable in the manufacture of airplanes. Just recently a large plant has been erected on the Texas coast for the extraction of magnesium from sea water.

Besides being used as a light alloy for airplane manufacture, magnesium is used in making incendiary bombs and flares. This metal is destined to become more widely used after the war.

Alloys of iron and steel. War is a battle of machines as well as of men. Machines must be made of metals which will stand great abuse. Thousands of tons of iron and steel go into the making of instruments of war. Steel for this purpose is hardened or given other special properties by the addition of other metals. *Manganese* is added to molten steel to remove the oxygen and sulfur and to make it harder. *Nickel* is added to steel to make it tough and hard. Nickel steel is used in making armor plate for naval and military use. Gun forgings, recoil springs, bullet jackets, ball bearings, gears, and high-speed tools are also made of steel alloyed with nickel. Fortunately, Canada is the world's largest producer of nickel. *Chromium* is used in the production of stainless steel. Chrome steel is also very hard and tough and will stand a great deal of abuse. Some armor plate and projectile casings are made of chrome steel. *Tungsten* is used in the production of high-speed tool steel. Tungsten steel has the useful property of retaining its hardness even at a red heat. This property makes it invaluable in the manufacture of high-speed tools for the production of military machines. Steel alloyed with tungsten is used as the core of high-caliber armor-piercing projectiles. *Vanadium* steel is tough and strong and is used in the springs of automobiles and guns.

Other materials essential in the prosecution of war—rubber. Eighty-five per cent of the world's rubber supply came from the Malay States and the Netherlands Indies at the outbreak of the second World War. This supply was virtually cut off from the United States when it entered the war. Tires were immediately placed on the priority list. The use of rubber for the manufacture of such things as erasers, hot-water bottles, jar rubbers, garden hose, and many other articles was banned. People began to drive their cars less and at a slower speed to conserve their tires.

Much of our available supply of rubber is used during wartime for the manufacture of tires for military trucks and airplanes. Enough rubber goes into the manufacture of one tank to equip ten ordinary cars with tires. Tons of rubber are used in the construction of one battleship.

The only hope we have of meeting these enormous needs lies in the ability of our chemists to produce enough synthetic rubber. You have learned how synthetic rubber may be produced. Large plants are being constructed to produce synthetic rubber on a large scale. Other chemists are working on the process of extracting natural rubber from the wild guayule bush, which covers thousands of acres in

Gathering seeds of guayule shrubs in California. Four-year-old plants yield 1000 pounds of rubber per acre

The General Tire & Rubber Co.

Mexico and the western United States. The Department of Agriculture has recently started the planting of 45,000 acres of guayule in several Western states. For the best economic results guayule rubber should be extracted from four-year-old shrubs, although one-year-old plants will yield some rubber.

Silk. Japan is the world's largest producer of silk. Since the outbreak of war with that country, the United States has had to use much of the available silk for essential war materials. The manufacture of silk hose and silk materials has been curtailed. "Nylon" hose and rayon clothing material have replaced silk, and women have been encouraged to use more cotton goods. You have learned how "Nylon," rayon, and other synthetic materials are produced. The capacity of plants manufacturing these synthetic materials has been increased to meet the new demands upon the industry, but some shortage may be noticed for some time to come. Silk and "Nylon" are used in the manufacture of parachutes, weather observation balloons, barrage balloons, and bags for the storage of explosives.

Petroleum. As the intensity of the war increases, the American motorist faces the prospect of having gasoline rationed. Already the octane content of automobile gasoline has been lowered. Airplane engines require a high-octane gasoline, and all types of engines use motor oil. The productive capacity of our refineries is great enough to provide gasoline and oil for our rapidly increasing air force, particularly since new cars cannot be bought and the motorist is driving his car less in order to conserve his tires. Petroleum chemists are now working on the problem of increasing the amount of high-octane gasoline which can be obtained from crude oil.

EXERCISES

1. What is the difference between strategic, critical, and essential minerals?
2. List three important war metals and describe the part they play in the successful prosecution of war.
3. How do the properties of aluminum and magnesium differ?
4. Describe the properties and wartime use of four steel alloys.
5. Why is there a shortage of rubber? What are the wartime uses of rubber?
6. Why is silk a necessary war material?
7. How does airplane gasoline differ from the gasoline generally used in automobiles?

Problem 4. Why is it necessary to ration commodities in time of war?

National objectives change during time of war. When a country enters into active warfare, there is one fundamental objective which must be attained—to win the war. In the United States the long-time objective of fostering and improving democracy as a way of living must be temporarily shelved in order that all the energy and resources of the nation may be marshaled together for an all-out effort to win the war and restore the peaceful way of living.

Any change in the objectives of a nation is always accompanied by corresponding changes in the daily life of its people. These changes are usually abrupt and far-reaching during a time of war. Therefore it is necessary for everyone to adjust quickly to a very different way of living—a way which demands many personal sacrifices.

Rationing is essential. In time of war every resource, both human and material, which can be utilized to win the war must be placed at the disposal of the government. Men and women must be conscripted, industry must be drafted for war production, and all materials must be placed at the disposal of the government for the defense of the nation.

When the productive capacity of industry is diverted to the production of war materials, many commodities used by our people in normal times cannot be produced. For example, when the automotive industry began to make airplanes for war use, the production of automobiles for civilian use had to be stopped. During wartime an industry which produces a necessary commodity will sometimes be allowed to continue to manufacture this commodity to a limited extent, only a part of its productive effort being diverted to the manufacture of war materials. Such limitation reduces the supply of the commodity below the demand, and it is therefore necessary to ration the commodity in order that all who need it may have some of it. Thus one reason for rationing sugar is that a portion of the refined sugar is being diverted to the production of other war materials.

Many foodstuffs and many other raw materials used in the manufacture of commodities which we consume in this country are either not produced here or not produced in sufficient quantities to supply the demand. In wartime the importation of such products is uncertain. It is therefore often necessary to ration such commodities. Much of our sugar is imported from Cuba and the Philippines. Since the importation of sugar from the Philippines has been stopped, our supply of sugar has decreased. This decrease is another factor in the rationing of this commodity. Our rubber supply from the Netherlands Indies has been cut off, and the rationing of rubber articles has been put into effect. Commodities such as tin cans, tin foil, and tin-plated utensils must be either withdrawn from the market or rationed. This is unavoidable because tin too was imported from the Netherlands Indies. As the intensity of naval warfare increases, many more imported products will have to be rationed.

Is hoarding patriotic? As, in time of war, the likelihood of rationing begins to be foreseen, there are always some people who begin buying certain commodities and storing them in attic or basement for use in times of strict rationing. Most people who do this are not conscious of the harm they are doing. Actually they are heaping hardships on their fellow men. Hoarders are often directly responsible for the rise in the price of commodities, and they often cause more strict rationing rules to be made than would otherwise be necessary. In addition, such people are taking away from their neighbors their rightful share of the commodity which is being hoarded. Wartime is a time for sharing—sharing the good as well as the bad. The person who hoards has little respect for the rights and privileges of his fellow men. Hoarding in time of war is not patriotic.

EXERCISES

1. What is the basic objective of war?
2. Give three reasons why rationing is essential during wartime.
3. Why is hoarding unpatriotic?

PROBLEMS FOR FURTHER STUDY

1. Make a study of the war materials being manufactured in or near your community.
2. In what ways has the war affected your daily living?
3. How can you help in conserving the resources of the country which are necessary in warfare?
4. How do cities protect themselves against air raids?
5. How are smoke screens produced, and what is their purpose in warfare?
6. What are the differences between the second World War and the first World War?
7. What part does agriculture play in the prosecution of war?
8. Make an extensive list of materials which need to be conserved in wartime.
9. Why are weather reports censored in time of war?
10. What effect does the condition of the weather have upon the use of war gases?

UNIT EXERCISES

A. The following statements are incomplete. On a separate piece of paper write whatever is necessary to complete each statement correctly. Do not write in this book.

1. Mustard gas is known as a liquid --(?)--.
2. Two lung-irritant gases are --(?)-- and --(?)--.
3. Important war materials are listed as --(?)--, --(?)--, and --(?)--.
4. Magnesium metal is used in the making of --(?)-- bombs.
5. "Dowmetals" contain 85–90% --(?)--.
6. Tungsten is used in the production of high-speed tool --(?)--.
7. One of the first commodities placed on the priority list during time of war is --(?)--.
8. --(?)-- gasoline is needed for airplanes.
9. The lead used in the making of bullets is hardened by the addition of the metal --(?)--.
10. During wartime it is necessary to --(?)-- materials of peace into materials of war.
11. The three general types of explosive bombs or shells are --(?)--, --(?)--, and --(?)--.
12. Torpedoes released from submarines, ships, or airplanes reach their objective by means of --(?)-- devices.
13. The explosive substance within bombs and projectiles is usually --(?)--.
14. Two of the four reasons for the terrific destructive power of a bomb dropped from an airplane are --(?)-- and --(?)--.
15. Another name for the magnesium bomb is the --(?)-- bomb.
16. One of the best home fire-fighting devices for extinguishing incendiary bombs is --(?)--.

17. The four kinds of war gases are known as --(?)--, --(?)--, --(?)--, and --(?)--.

18. The essential materials in a gas mask are a fibrous filter material, --(?)--, and --(?)--.

B. Some of the following statements are true, and some are false. On a separate sheet of paper write the word *true* for each statement that is true and the word *false* for each statement that is false. Write nothing for those statements about which you are doubtful. Rewrite the false statements so that they are true.

1. Chlorine is an ideal poisonous gas.

2. Phosgene is a liquid vesicant.

3. Sneeze gases are known as lachrymators.

4. Mustard gas and lewisite are known as blister gases.

5. Water should be directed on a burning incendiary bomb to extinguish it.

6. Mustard gas is the most dreaded of all war gases.

7. Liquid vesicants are absorbed by the skin.

8. The breathing of lachrymatory gases very often proves fatal.

9. A good United-States-army gas mask offers complete protection to the respiratory tract of a person in a poisonous-gas atmosphere.

10. The activated charcoal in the canister of a gas mask adsorbs poisonous gases.

11. Gas masks have in them materials which regenerate fresh air and pure oxygen.

12. Mustard gas is a very persistent gas.

13. When phosgene enters the lungs, it reacts with the moisture to produce sulfuric acid and carbon monoxide.

14. After a mustard gas attack a person who must remain in the gassed area should not remove his gas mask for at least twelve hours.

15. Sternutators will cause vomiting when they are breathed into the lungs.

16. The activated carbon in gas masks will effectively remove sternutators.

17. Incendiary bombs generally weigh about 1000 pounds.

18. Incendiary bombs are made of aluminum.

19. Aluminum is a strategic war material.

20. Poisonous war gases have characteristic odors.

REFERENCES FOR FURTHER READING

Lefebure, Victor. *The Riddle of the Rhine.* The Chemical Foundation, Inc., New York, 1929.

Ley, Willy. *Bombs and Bombing.* Modern Age Books, Inc., New York, 1941.

Prentiss, A. M. *Chemicals in War.* McGraw-Hill Book Company, Inc., New York, 1937.

Roush, G. A. *Strategic Mineral Supplies.* McGraw-Hill Book Company, Inc., New York, 1939.

Fire Protection in Civilian Defense. United States Office of Civilian Defense, Washington, D.C., 1941.

A Handbook for Auxiliary Firemen. United States Office of Civilian Defense, Washington, D.C., 1941.

A Handbook for Decontamination Squads. United States Office of Civilian Defense, Washington, D.C., 1941.

A Handbook for Demolition and Clearance Crews. United States Office of Civilian Defense, Washington, D.C., 1941.

Protection against Gas. United States Office of Civilian Defense, Washington, D.C., 1941.

Epilogue

You have completed a year's study of chemistry, but it is hoped that you have only just begun what will prove to be a lifelong study of the applications of chemistry to your everyday living.

Chemistry, as an exact science, is only about one hundred and fifty years old, but in that short time we have found that it has changed our lives in countless ways. Our country and the whole world have moved forward. Chemistry has played an important part in this movement.

Chemistry's chief activity has been research, the adventuring spirit of which is necessary to sustain the life of our civilization. There is no evidence to indicate that this will not continue. We may expect more and more research by universities, colleges, and private organizations in the future. Out of this research there are bound to come advances as yet undreamed of.

You have learned of some of the fruits of chemical research. Because of it you have comforts and advantages unknown to your parents. You have better homes, better things in them, more attractive clothes, and fresher and more nutritious food. Your doctor and dentist have learned much from chemical research which has added to your health. The new knowledge of vitamins and hormones means much to your personal living. Public health has made significant gains as a result of chemical research. Water supplies have been made pure and healthful. Farm crops have been increased, and waste products from the farms have been made into useful and valuable things. In other words, chemistry has given man an opportunity to secure the good things of life by taking them from nature and not from someone else.

The new frontiers of the future will not be new places on the map of the world but instead will be the molecules of matter. New spirit, new hopes, — in short, new life, — are ahead of us through chemistry.

APPENDIX

I. The Metric System

UNITS OF LENGTH

1 centimeter (cm) = 10 millimeters (mm)
1 meter (m) = 100 centimeters
1 kilometer (km) = 1000 meters

Unit Equivalents (approximate)

1 inch (in.) = 2.54 centimeters
1 meter = 39.37 inches
1 kilometer = 0.62 mile

UNITS OF VOLUME

1 liter (l) = 1000 cubic centimeters (cc), or
1000 milliliters (ml)

Unit Equivalent (approximate)

1 liter = 1.057 liquid quarts (qt)

UNITS OF WEIGHT

1 gram (g) = 1000 milligrams (mg)
1 kilogram (kg) = 1000 grams

Unit Equivalents (approximate)

1 ounce (oz) = 28.36 grams
1 gram = 15.43 grains
1 pound (lb) = 453.6 grams
1 kilogram = 2.2 pounds (avoirdupois)

II. Conversion of Thermometer Readings from One Scale to Another

Almost everyone is familiar with the Fahrenheit thermometer scale. As you know, the centigrade scale is the one most commonly used in scientific work. There is, however, another thermometer scale, called the *absolute* scale, which is also used in scientific work. This scale is based upon the calculation of the temperature at which molecular motion in matter ceases. This temperature, known as absolute zero, is 273° below zero on the centigrade scale.

You should note that the boiling point of water is 212° F, 100° C, or 373° A, and the freezing point of water is 32° F, 0° C, or 273° A.

The conversion of thermometer readings from one scale to another may be made according to the following rules:

1. To convert Fahrenheit to centigrade subtract 32 from the Fahrenheit reading and multiply by $\frac{5}{9}$.

$$C = \tfrac{5}{9}(F - 32)$$

2. To convert centigrade to Fahrenheit multiply the centigrade reading by $\frac{9}{5}$ and add 32.

$$F = \tfrac{9}{5}C + 32$$

3. To convert centigrade to absolute add 273 to the centigrade reading.

$$A = C + 273$$

4. To convert Fahrenheit to absolute convert the Fahrenheit reading to centigrade and then add 273 to the centigrade reading.

III. How to Compute Changes in the Volumes of Gases Due to Changes in Temperature and Pressure

In Unit 9 you learned how the volumes of gases in chemical reactions may be determined under conditions of standard temperature and pressure (S.T.P.). (Standard temperature is 0° C and standard pressure is 760 millimeters.) However, in actual practice conditions of standard temperature and pressure do not prevail, and it is necessary to compute the volumes of gases under varying conditions. To make such computations requires a knowledge of two fundamental gas laws—Charles's law and Boyle's law.

Charles's law. On page 32 you learned that when a gas is heated, its volume is increased. The increase in volume occurs in accordance with a definite law, known as Charles's law. *The volumes occupied by a given weight of gas at different temperatures are proportional to the absolute temperatures, provided the pressure remains constant.*

If we designate the volume and temperature under one set of conditions as V_1 and T_1 and the volume and temperature under a new set of conditions as V_2 and T_2, we have the law expressed in formula form as follows:

$$\frac{V_1}{V_2} = \frac{T_1}{T_2} \quad \text{or} \quad V_2 = \frac{V_1 T_2}{T_1} \text{ (Pressure constant)}$$

It may also be expressed as follows:

$$\text{New volume of gas} = \frac{\text{old volume} \times \text{new temperature}}{\text{old temperature}}$$

It was shown by Charles that the temperatures used in this formula in computing volume changes must be expressed in terms of the absolute scale. He discovered that when a gas at 0° C is heated, its volume will be increased by $\frac{1}{273}$ of its volume at 0° C for every degree that the temperature is raised, and the volume will be decreased by $\frac{1}{273}$ for every degree that the temperature is lowered, provided the pressure remains the same.

Example: What volume will 65 liters of oxygen occupy if its temperature is changed from $-13°$ C to 27° C?

1. Change the temperatures to the absolute scale:

$$-13° \text{ C} + 273° = 260° \text{ A}$$
$$27° \text{ C} + 273° = 300° \text{ A}$$

2. Substitute in the formula above:

$$\text{New volume} = \frac{65 \times 300}{260} = 75 \text{ liters}$$

EXERCISES

1. The volume of a gas was 780 cubic centimeters at a temperature of 23° C. What will be its volume at 0° C, the pressure remaining the same?

2. What volume will 1 liter of a gas at S.T.P. have if the temperature is raised to 100° C, the pressure remaining the same?

3. The volume of air is 500 liters, and the temperature is 25° C. The air is heated until the volume is increased to 1000 liters. What will be the new temperature, provided the pressure remains the same?

4. The volume of oxygen is 22.4 liters at 0° C. What will be its volume at 27° C, the pressure remaining the same?

Boyle's law. You are aware of the fact that when a gas is compressed, its volume decreases. This fact was stated by Boyle as follows: *The volume occupied by a given weight of a gas varies inversely with the pressure, provided the temperature remains constant.* If we designate the pressure and volume under one set of conditions as P_1 and V_1 and the pressure and volume under a new set of conditions as P_2 and V_2, we have the law expressed in formula form as follows:

$$\frac{V_1}{V_2} = \frac{P_2}{P_1}, \quad \text{or} \quad V_2 = \frac{V_1 P_1}{P_2} \text{ (Temperature constant)}$$

It may also be expressed as follows:

$$\text{New volume of gas} = \frac{\text{old volume} \times \text{old pressure}}{\text{new pressure}}$$

Example: A quantity of oxygen measured 150 liters under a pressure of 750 millimeters. What would its volume measure under a pressure of 800 millimeters if the temperature remained the same?

$$\text{New volume} = \frac{150 \times 750}{800} = 140.6 \text{ liters}$$

EXERCISES

1. The volume of a gas measured 180 cubic centimeters at a pressure of 244 millimeters. What will be its volume if the pressure is increased to 780 millimeters, the temperature remaining constant?

2. A balloon contains 800,000 cubic feet of helium when the barometric reading is 740 millimeters. The height of the balloon changes, and the barometric reading is 640 millimeters. What will be the new volume of the gas in the balloon, the temperature remaining constant?

Change in volume due to a simultaneous change in pressure and temperature. Most changes in the volume of a gas are caused by changes in both pressure and temperature. You may make corrections for these changes by first determining the change due to pressure according to Boyle's law and then calculating the change due to temperature according to Charles's law. These two laws may be expressed together as follows:

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}, \quad \text{or} \quad V_2 = V_1 \times \frac{T_2}{T_1} \times \frac{P_1}{P_2}$$

It may also be expressed as follows:

$$\text{New volume} = \text{old volume} \times \frac{\text{new temperature}}{\text{old temperature}} \times \frac{\text{old pressure}}{\text{new pressure}}$$

Example: A quantity of air measured 200 liters when the barometric reading was 750 millimeters and the temperature was 27° C. What volume would the air occupy if the pressure were lowered to 700 millimeters and the temperature to – 3° C?

$$\text{New volume} = 200 \times \tfrac{270}{300} \times \tfrac{750}{700} = 192.9 \text{ liters}$$

EXERCISES

1. Calculate what would be the volume of 218 cubic centimeters of oxygen at 25° C and 800 millimeters if a change were made to standard temperature and pressure.

2. Determine how many liters of oxygen will be evolved when 43.7 grams of potassium chlorate are heated and the gas is collected at 750 millimeters pressure and 27° C.

3. A quantity of zinc is treated with HCl and the hydrogen collected. The volume of the hydrogen is found to be 100 cubic centimeters at 27° C and 750 millimeters. Calculate (*a*) the volume of this hydrogen at standard conditions and (*b*) the weight of the zinc used in producing this volume of hydrogen.

4. At 27° C and 800 millimeters pressure a quantity of ammonia gas measured 20 liters. (*a*) What would the volume be under standard conditions? (*b*) What would the volume be if the pressure were 960 millimeters and the temperature 250° C?

IV. The Periodic Table

As early as 1829 Döbereiner recognized resemblances in the properties of certain elements. In 1864 Newlands arranged the elements in the order of their atomic weight and discovered that certain properties were repeated with each eighth element. In 1870 the Russian chemist Mendeléeff, building on the work of Newlands, worked out a system of classification of the elements based on their atomic weights which we now call the *periodic table.*

The brilliant young English chemist Moseley (1887–1915) discovered, through a study of X-ray spectra of the elements, the law of atomic numbers. The atomic number of each atom equals the total number of excess protons in the nucleus of the atom. The atomic numbers of the elements run from 1 to 92. In terms of atomic numbers the periodic law may be stated as follows: *The chemical properties of the elements are periodic functions of their atomic numbers.* When arranged in a table according to their atomic numbers, the elements appear in almost the same position as in Mendeléeff's table. Certain irregularities present in Mendeléeff's table, in which the elements were arranged according to atomic weights, do not appear when the elements are arranged according to their atomic numbers, as in the table prepared by Moseley.

What facts may be gained from a study of the periodic table? 1. The elements are arranged in the order of their atomic numbers, from 1 to 92.

2. The elements making up each horizontal row are called a *period.* The elements in each vertical column resemble each other closely in properties and are called a *group.*

Beginning with the element helium, an inert element with atomic number 2, the elements with the next seven atomic numbers are arranged in a horizontal row. The properties of these eight elements are quite different. The element neon, with atomic number 10, has properties very similar to those of helium; so it is placed in a new horizontal row, or period, just beneath helium, in Group 0. In a like manner, each of the succeeding elements falls in a group under elements which have similar properties. For example, chlorine falls under fluorine in Group VII. These elements have similar properties. The next element after chlorine is argon, atomic number 18. Since it is an inert element, it is placed under neon, in Group 0, as the first member of a new period. All the other elements are similarly arranged in the table.

3. Hydrogen, which has atomic number 1, has many of the properties of a metal but is a gas. Since it does not fall naturally into any of the periods with other elements, it is placed in a period of its own, Period 0.

4. The elements in each group fall into two families, *A* and *B*. The members of each family resemble each other closely in properties; that is, in Group I, lithium, sodium, and potassium, members of the *A* family (commonly known as the sodium family), have many similar properties, and copper, silver, and gold, in family *B* of this group, also have many similar properties.

5. The principal valence of most of the elements in each group is usually the same, and a type formula for the oxide, chloride, or hydride may be written. If we let R stand for the symbol of the element in a group, the type formula may be expressed as R_2O or RCl for Group I and as RO or RCl_2 for Group II, etc.

6. The atomic weights (with few exceptions) increase as you read from left to right in each period and from top to bottom in each group.

THE PERIODIC ARRANGEMENT OF THE ELEMENTS ACCORDING TO ATOMIC NUMBERS

PERIODS	GROUP 0	GROUP I	GROUP II	GROUP III	GROUP IV	GROUP V	GROUP VI	GROUP VII	GROUP VIII		
	TYPE	R_2O, RCl	RO, RCl_2	R_2O_3,RCl_3	RO_2, RCl_4	R_2O_5,RCl_5	RO_3, H_2R	R_2O_7, HR	TRANSITION ELEMENTS		
	FAMILIES	A B	A B	A B	A B	A B	A B	A B			
0		**1** Hydrogen = 1.0080									
1	**2** Helium = 4.003	**3** Lithium = 6.940	**4** Beryllium = 9.02	**5** Boron = 10.82	**6** Carbon = 12.010	**7** Nitrogen = 14.008	**8** Oxygen = 16.000	**9** Fluorine = 19.00			
2	**10** Neon = 20.183	**11** Sodium = 22.997	**12** Magnesium = 24.32	**13** Aluminum = 26.97	**14** Silicon = 28.06	**15** Phosphorus = 30.98	**16** Sulfur = 32.06	**17** Chlorine = 35.457			
3	**18** Argon = 39.944	**19** Potassium = 39.096	**20** Calcium = 40.08	**21** Scandium = 45.10	**22** Titanium = 47.90	**23** Vanadium = 50.95	**24** Chromium = 52.01	**25** Manganese = 54.93	**26** Iron = 55.85	**27** Cobalt = 58.94	**28** Nickel = 58.69
		29 Copper = 63.57	**30** Zinc = 65.38	**31** Gallium = 69.72	**32** Germanium = 72.60	**33** Arsenic = 74.91	**34** Selenium = 78.96	**35** Bromine = 79.916			
4	**36** Krypton = 83.7	**37** Rubidium = 85.48	**38** Strontium = 87.63	**39** Yttrium = 88.92	**40** Zirconium = 91.22	**41** Columbium = 92.91	**42** Molybdenum = 95.95	**43** Masurium	**44** Ruthenium = 101.7	**45** Rhodium = 102.91	**46** Palladium = 106.7
		47 Silver = 107.88	**48** Cadmium = 112.41	**49** Indium = 114.76	**50** Tin = 118.70	**51** Antimony = 121.76	**52** Tellurium = 127.61	**53** Iodine = 126.92			
5	**54** Xenon = 131.3	**55** Cesium = 132.91	**56** Barium = 137.36	**57–71** Rare Earths	**72** Hafnium = 178.6	**73** Tantalum = 180.88	**74** Tungsten = 183.92	**75** Rhenium = 186.31	**76** Osmium = 190.2	**77** Iridium = 193.1	**78** Platinum = 195.23
		79 Gold = 197.2	**80** Mercury = 200.61	**81** Thallium = 204.39	**82** Lead = 207.21	**83** Bismuth = 209.00	**84** Polonium = 210.0	**85** Alabamine = 221(?)			
6	**86** Radon = 222	**87** Virginium = 224(?)	**88** Radium = 226.05	**89** Actinium = 227(?)	**90** Thorium = 232.12	**91** Protoactinium = 231	**92** Uranium = 238.07				

7. The metallic elements are found in Groups I, II, and III of the table, and the nonmetallic elements are found in Groups V, VI, and VII.

8. Elements in the center of the table, Group IV, show both basic and acidic properties; that is, they show some of the properties of both metals and nonmetals.

9. The inert elements are placed in Group 0, since they were not known to Mendeléeff and were not in his table. They have eight electrons in the outside orbit and do not unite with other elements to form compounds.

10. Following manganese in Period 3, the next three elements, iron (atomic number 26), cobalt (atomic number 27), and nickel (atomic number 28), have atomic weights much nearer together than those of any of the elements of smaller atomic numbers. They have very similar properties, which are different from the properties of the elements of any other group; so they are placed in a new group, Group VIII. They are sometimes called the transition elements.

11. As you go from left to right in each period, the basic properties of the elements decrease, and the acidic properties increase. For example, in Period 2, sodium, in Group I, forms a strong base; magnesium, in Group II, forms a weak base; aluminum, in Group III, forms a compound which has the properties of a weak base as well as a weak acid; phosphorus, in Group V, forms a weak acid; and chlorine, in Group VII, forms a very strong acid.

12. In each group, as you read from top to bottom, the atomic weight increases, and the density of the elements increases.

13. In general, the chemical and physical properties of the members of a family show gradual changes with changes in atomic weight and atomic number. For example, as you read down a group, the valence electrons of each element are located farther from the nucleus. Therefore the activity of the metals increases, and the activity of nonmetals decreases. (See page 83.) Moreover, as you read down a group, the melting points and boiling points of metals decrease, whereas the melting points and boiling points of nonmetals increase. This gradual variation in the properties of the members of a family is shown more markedly in the halogen and sodium families than in others. The tables below show the important properties of the members of these two families.

14. Elements with atomic numbers 57 to 71 are called the *rare earths.* They resemble each other closely in properties and are placed together in the table.

THE HALOGEN FAMILY

ELEMENT	ATOMIC NUMBER	ATOMIC WEIGHT	DEGREE OF ACTIVITY	MELTING POINT	BOILING POINT	DENSITY OF LIQUID	PHYSICAL STATE AT ROOM TEMPERATURE	COLOR
Fluorine	9	19.00	Very active	– 223° C	– 187° C	1.14	Gas	Straw-colored
Chlorine	17	35.46	Increasing ↑	– 101° C	– 34.6° C	1.507	Gas	Light green
Bromine	35	79.92		– 7° C	58.7° C	3.12	Liquid	Red
Iodine	53	126.92	Least active	113° C	184.3° C	4.94	Solid	Black lustrous crystal solid; violet gas

THE SODIUM FAMILY

ELEMENT	ATOMIC NUMBER	ATOMIC WEIGHT	DEGREE OF ACTIVITY	MELTING POINT	BOILING POINT	DENSITY
Lithium	3	6.94	Least active	186° C	1400° C	0.53
Sodium	11	23.0	Increasing ↓	97.5° C	880° C	0.97
Potassium	19	39.1		62.3° C	760° C	0.87
Rubidium	37	85.5		38° C	696° C	1.53
Cesium	55	132.9	Most active	26° C	670° C	1.87

V. *Solubilities of Some Common Salts*

	ACETATE	BROMIDE	CARBONATE	CHLORATE	CHLORIDE	CHROMATE	HYDROXIDE	IODIDE	NITRATE	OXIDE	PHOSPHATE	SILICATE (ORTHO)	SULFATE	SULFIDE
	$C_2H_3O_2$	Br	CO_3	ClO_3	Cl	CrO_4	OH	I	NO_3	O	PO_4	SiO_4	SO_4	S
Aluminum (Al)	S	S		S	S		HS	S	S	HS	HS	HS	S	HS
Ammonium (NH_4)	S	S	S	S	S	S	S	S	S		S		S	S
Barium (Ba)	S	S	HS	S	S	HS	S	S	S	HS	HS	HS	I	S
Calcium (Ca)	S	S	HS	S	S	SS	S	S	S	SS	HS	HS	SS	SS
Cobalt (Co)	S	S	HS	S	S	HS	HS	S	S	HS	HS	HS	S	HS
Copper (Cu)	S	S	HS	S	S	S	HS	S	S	HS	HS	HS	S	HS
Iron (ferric) (Fe^{+++})	S	S		S	S	S	HS	S	S	HS	HS	HS	S	HS
Iron (ferrous) (Fe^{++})	S	S	HS	S	S		HS	S	S	HS	HS	HS	S	HS
Lead (Pb)	S	SS	HS	S	SS	HS	HS	SS	S	HS	HS	HS	I	HS
Magnesium (Mg)	S	S	HS	S	S	S	HS	S	S	HS	HS	HS	S	HS
Manganese (Mn)	S	S	HS	S	S	S	HS	S	S	HS	HS	HS	S	HS
Mercury (mercuric) (Hg^{++})	S	S	HS	S	S	SS		HS	S	HS	HS		SS	I
Mercury (mercurous) (Hg^{+})	S	HS		S	HS	HS		HS	S	HS	HS		SS	
Nickel (Ni)	S	S	HS	S	S	HS	HS	S	S	HS	HS	HS	S	HS
Potassium (K)	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Silver (Ag)	S	I	HS	S	I	HS		I	S	HS	HS		SS	HS
Sodium (Na)	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Tin (stannous) (Sn)	S	S			S	HS	HS	S		HS	HS		S	HS
Zinc (Zn)	S	S	HS	S	S	S	HS	S	S	HS	HS	HS	S	HS

S—the salts are soluble in water.
HS—the salts are insoluble in water, but are soluble in either HCl or HNO_3 or in both.
I—the salts are insoluble in water and in acids.
SS—the salts are slightly soluble in water and slightly or readily soluble in acids.

VI. Vitamins Present in Some Common Foods

FOOD	A	B_1	B_2, OR G	C	D
Apples, raw	+	+	++	++	–
Bacon	+	++	++	?	–
Beans, string	++	++	++	++	–
Beef, lean	+	++	++	–	–
Bread, white	–	+	–	–	–
Bread, whole wheat	+	+++	+	–	–
Butter	+++	–	–	–	– to +
Cabbage, green, raw	+	++	++	+++	–
Carrots	+++	++	–	++	–
Celery	+	++	?	?	–
Cheese, American	+++	–	++	–	–
Cod-liver oil	+++	–	–	–	+++
Eggs	+++	++	+++	–	++
Fish, lean	–	+	+	–	–
Kidney	++	++	+++	–	–
Lamb	+	++	++	–	–
Lettuce	++	++	++	++	–
Liver	+++	++	+++	++	+
Milk, skim	+	++	+++	–	–
Milk, whole	+++	++	+++	+	–
Oranges	++	+	++	+++	–
Peanuts	+	++	+	–	–
Peas, green	+++	++	++	+++	–
Pork	–	++	++	–	–
Potatoes	–	++	+	++	–
Spinach	+++	++	++	++	–
Tomatoes, raw or canned	+++	++	+	+++	–
Veal	–	–	++	–	–

+ contains the vitamin
++ good source of the vitamin
+++ excellent source of the vitamin
? presence doubtful or unknown
– no appreciable amount known to be present

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TABLE OF THE ELEMENTS

ELEMENT	SYMBOL OF ELEMENT	VALENCE	ATOMIC NUMBER	ATOMIC WEIGHT	SPECIFIC GRAVITY	MELTING POINT, CENTICRADE
Actinium	Ac		89	(227)[2]		
Alabamine [1]	Ab		85	(221)[2]		
Aluminum	Al	3	13	26.97	2.702	660
Antimony	Sb	3, 5	51	121.76	6.684	630.5
Argon	A	0	18	39.94	0.0178	–189.2
Arsenic	As	3, 5	33	74.91	2.0 to 5.7	814.0
Barium	Ba	2	56	137.36	3.5	850
Beryllium	Be	2	4	9.02	1.85	1280
Bismuth	Bi	3, 5	83	209.00	9.80	271.0
Boron	B	3	5	10.82	2.45	2200?
Bromine	Br	1	35	79.92	3.4	–7.2
Cadmium	Cd	2	48	112.41	8.6	320.9
Calcium	Ca	2	20	40.08	1.5	810
Carbon	C	4	6	12.010	2.25	3500
Cerium	Ce	3, 4	58	140.13	6.90	640
Cesium	Cs	1	55	132.91	1.90	26.0
Chlorine	Cl	1	17	35.457	0.0032	–101.5
Chromium	Cr	2,3,6	24	52.01	7.1	1615.0
Cobalt	Co	2, 3	27	58.94	8.9	1480
Columbium	Cb	5	41	92.91	8.4	1950
Copper	Cu	1, 2	29	63.57	8.92	1083.0
Dysprosium	Dy	3	66	162.46		
Erbium	Er	3	68	167.2	4.77	1250
Europium	Eu	3	63	152.0		
Fluorine	F	1	9	19.00	0.0017	–223
Gadolinium	Gd	3	64	156.9		
Gallium	Ga	3	31	69.72	5.9	29.75
Germanium	Ge	4	32	72.60	5.36	958.5
Gold	Au	1, 3	79	197.2	19	1063.0
Hafnium	Hf	4	72	178.6		1700
Helium	He	0	2	4.003	0.00018	–271.0
Holmium	Ho	3	67	163.5		
Hydrogen	H	1	1	1.0080	0.000089	–259.0
Illinium	Il	3	61	146[2]		
Indium	In	3	49	114.76	7.3	155.0
Iodine	I	1	53	126.92	4.93	113.5
Iridium	Ir	4	77	193.1	22.4	2350
Iron	Fe	2, 3	26	55.85	7.86	1535.0
Krypton	Kr	0	36	83.7	0.0037	–169.0
Lanthanum	La	3	57	138.92	6.15	286.0
Lead	Pb	2, 4	82	207.21	11.34	327.5
Lithium	Li	1	3	6.940	0.534	186
Lutecium	Lu	3	71	174.99		
Magnesium	Mg	2	12	24.32	1.74	651.0
Manganese	Mn	2,3,7	25	54.93	7.2	1260
Masurium	Ma	2,3,7	43			2300
Mercury	Hg	1, 2	80	200.61	13.56	–38.8
Molybdenum	Mo	4, 6	42	5.95	10.2	2620
Neodymium	Nd	3	60	144.27	6.9	840
Neon	Ne	0	10	20.183		–248.67
Nickel	Ni	2, 3	28	58.69	8.90	1452.0
Nitrogen	N	3, 5	7	14.008	0.810	–209.60
Osmium	Os	6, 8	76	190.2	22.48	2700.0
Oxygen	O	2	8	16.000	0.001429	–218
Palladium	Pd	2, 4	46	106.7	12.0	1549
Phosphorus	P	3, 5	15	30.98	1.82 to 2.25	44.2
Platinum	Pt	2, 4	78	195.23	21.45	1755.0
Polonium	Po	2,4,6	84	210.0		
Potassium	K	1	19	39.096	0.86	62.3
Praseodymium	Pr	2	59	140.92	6.5	940
Protoactinium	Pa		91	231		
Radium	Ra	2	88	226.05	5	960
Radon	Rn	0	86	222	0.00973	
Rhenium	Re		75	186.31		
Rhodium	Rh	3	45	102.91	12.5	1955.0
Rubidium	Rb	1	37	85.48	1.53	38.5
Ruthenium	Ru	6, 8	44	101.7	12.2	2450
Samarium	Sa	3	62	150.43	7.7	1300
Scandium	Sc	3	21	45.10	2.5	1200
Selenium	Se	2,4,6	34	78.96	4.3	220
Silicon	Si	4	14	28.06	2.4	1420
Silver	Ag	1	47	107.880	10.5	960.5
Sodium	Na	1	11	22.997	0.97	97.5
Strontium	Sr	2	38	87.63	2.6	800
Sulfur	S	2,4,6	16	32.06	1.96 to 2.07	106.8
Tantalum	Ta	5	73	180.88	16.6	2850
Tellurium	Te	2,4,6	52	127.61	6.24	452.0
Terbium	Tb	3	65	159.2		
Thallium	Tl	1, 3	81	204.39	11.85	302.0
Thorium	Th	4	90	232.12	11.2	1845
Thulium	Tm	3	69	169.4		
Tin	Sn	2, 4	50	118.70	6.99	231.85
Titanium	Ti	4	22	47.90	4.5	1800.0
Tungsten	W	6	74	183.92	19.3	3370.0
Uranium	U	4, 6	92	238.07	18.7	1850
Vanadium	V	3, 5	23	50.95	5.96	1710
Virginium [1]	Vi		87	(224)[2]		
Xenon	Xe	0	54	131.3	0.0058	–140
Ytterbium	Yb	3	70	173.04	5.51	1800.0
Yttrium	Yt	3	39	88.92	5.51	1490
Zinc	Zn	2	30	65.38	7.14	419.43
Zirconium	Zr	4	40	91.22	6.4	1700

[1] Discovery reported but not confirmed.

[2] Approximate atomic weight.

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